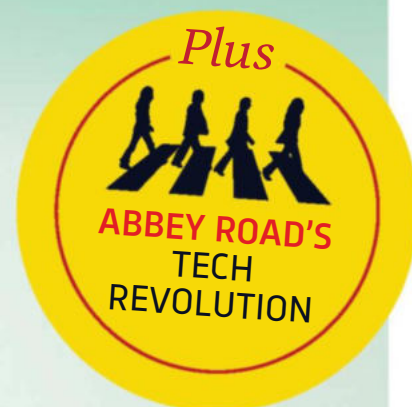


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**Q&A**

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WHITE?

CAN WE  
CLONE A  
NEANDERTHAL?

HOW DO  
CHAMELEONS  
CHANGE COLOUR?

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# WELCOME



I've never been one for food fads. I tried a wheatgrass shot once. But I could probably save myself £3 and lick the bottom of a lawnmower if I wanted to repeat the experience. I feel the same way about spiralisers, paleo diets and something called freekeh. To me, these culinary crazes feel like marketers trying to sell us something that's been around forever, but at a premium price.

I'm just not interested in how kale, or any other brassica, is going to change my life.

But how healthy are everyday foods? That's something I *do* want to know. I consume a lot of salt, butter, eggs, coffee and bacon (and now I want breakfast). Nothing deadly, and often not all in one sitting, but all of the above continually make the news, sometimes as the hero or more often as the villain. Take eggs, for example. Some news sites report that they're "the healthiest food on the planet" while others describe the humble egg as a "cholesterol time bomb". And what about butter? I love the stuff, but how lethal are the saturated fats lurking within?

To find out the science behind the headlines and get the most up-to-date research on what's really good or bad for you, we enlisted our friends from the brilliant series *Trust Me, I'm a Doctor*. Read their verdict on p40. Enjoy the issue!

*Daniel Bennett*

Daniel Bennett, Editor

## IN THIS ISSUE



### SALEYHA AHSAN

A&E doctor Saleyha is a familiar face as a member of the *Trust Me, I'm A Doctor* team. This month, she reveals which foods to dodge and which to devour. → p40



### BELLA BATHURST

Bella, a writer and photojournalist, lost her hearing. Then, it slowly returned. We introduce her to Vanessa Potter, who lost and gained her sight. → p58



### JOSS GABBATISS

Science writer Josh loves the quirky side of nature. And what could be weirder than a subterranean social network used by plants? → p62



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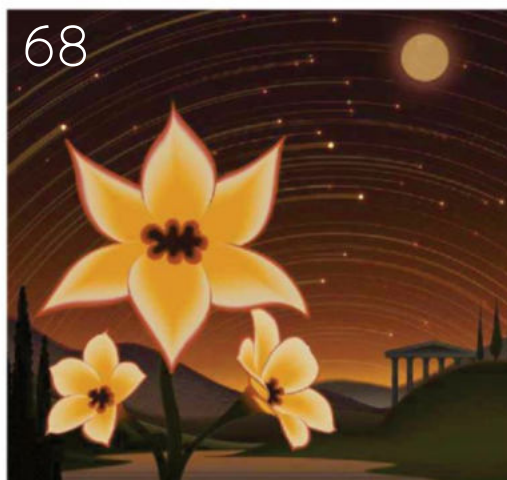
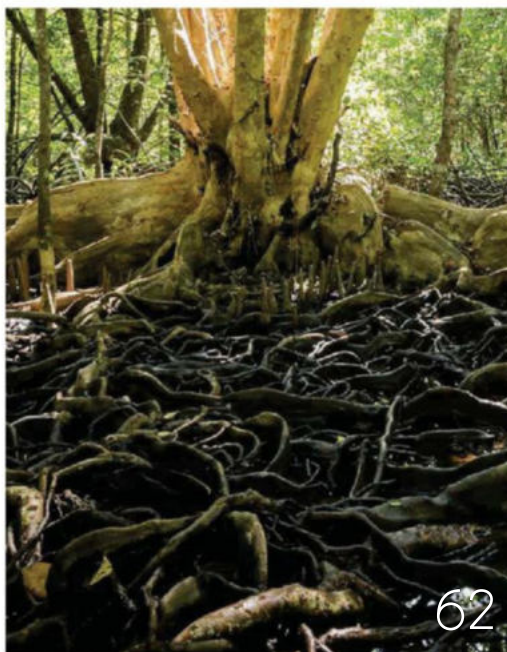
**58** Bella Bathurst lost her hearing; Vanessa Potter's sight disappeared. Both their senses later returned. They tell us their stories.

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## MORE FOR YOU

Don't forget that *BBC Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. [sciencefocus.com](http://sciencefocus.com)



## Special issue



### ANSWERS TO LIFE'S BIG QUESTIONS

The latest special edition from the *BBC Focus* team explores the incredible science behind everyday life. Discover why cats hate water, why we forget, how astronauts poo, plus over 230 more fascinating facts.









EYE OPENER

## Honey trap

CALIFORNIA,  
USA

What a sweet shot! Developing worker honeybees nestle inside the individual wax cells that make up the insects' honeycomb.

As bees develop, they undergo holometabolous metamorphosis – a lifecycle that includes four stages: egg; larva; pupa and adult. In this photograph, protective wax caps put in place by worker bees have been removed, revealing the pupae just days before they are ready to emerge as fully grown adults.

"These bees are pale because their cuticle [their outer shell] has not yet hardened – in fact even when they emerge as adults they can take a few hours to fully harden," says Adam Hart, a BBC presenter and entomologist. "This means that very young bees are more or less unable to sting – a great time to mark them if you want to follow individuals through their lives!"

PHOTO: NATIONAL GEOGRAPHIC IMAGES









## EYE OPENER

# Like the wind

**VARIS,**  
FRANCE

Yes, that is someone cycling. Down the side of a mountain. This is Eric Barone, also known as Le Baron Rouge, setting a new world speed record for mountain biking on 18 March 2017. He reached a speed of 227.7km/h (141.5mph) while bombing it down the snow track at Vars ski resort in France.

"The only thing propelling the bike was gravity," explains Marc Amerigo, lead engineer of the project, "so Eric's bike, helmet and latex suit were all designed to minimise air resistance. We made a 3D scan of the bike with Eric sitting on it, and then added external 'fairings' to the frame to get an optimal airflow. He also has pieces of foam under his suit to make him as aerodynamic as possible."

Eric Barone has a taste for speed. As well as working as a stunt double for actors like Sylvester Stallone and Jean-Claude Van Damme, the 56-year-old Frenchman also holds the world record speed for bicycle on gravel – an equally impressive 172km/h (107mph).

PHOTO: GETTY



# Dr Saunders strikes back

**Psychiatrist suffers stroke, then analyses symptoms to help others**

Dr Tony Saunders always looked after his health, so it seemed doubly unfair when he collapsed with a major stroke in the gym.

Tony's family were worried that he could die, as stroke takes a life every 13 minutes in the UK. And it's the leading cause of severe adult disability.

Fortunately, with excellent treatment, Tony eventually returned to work.

But Tony noticed that discussing his stroke made him anxious – he even started stuttering.

As a psychiatrist, he identified this as post-traumatic stress disorder. He then realised that, on top of his medical training, he now had valuable first-hand experience of stroke.

So Tony struck back by overcoming his anxiety, and giving talks to medical students. As a result,

a new generation of doctors are supporting their patients with powerful new techniques.

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# DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

JUNE 2017

EDITED BY JASON GOODYER

Computer concept of brain  
nerve cells affected by  
Alzheimer's disease

BRAIN

## ANTIDEPRESSANT COULD HELP FIGHT DEMENTIA

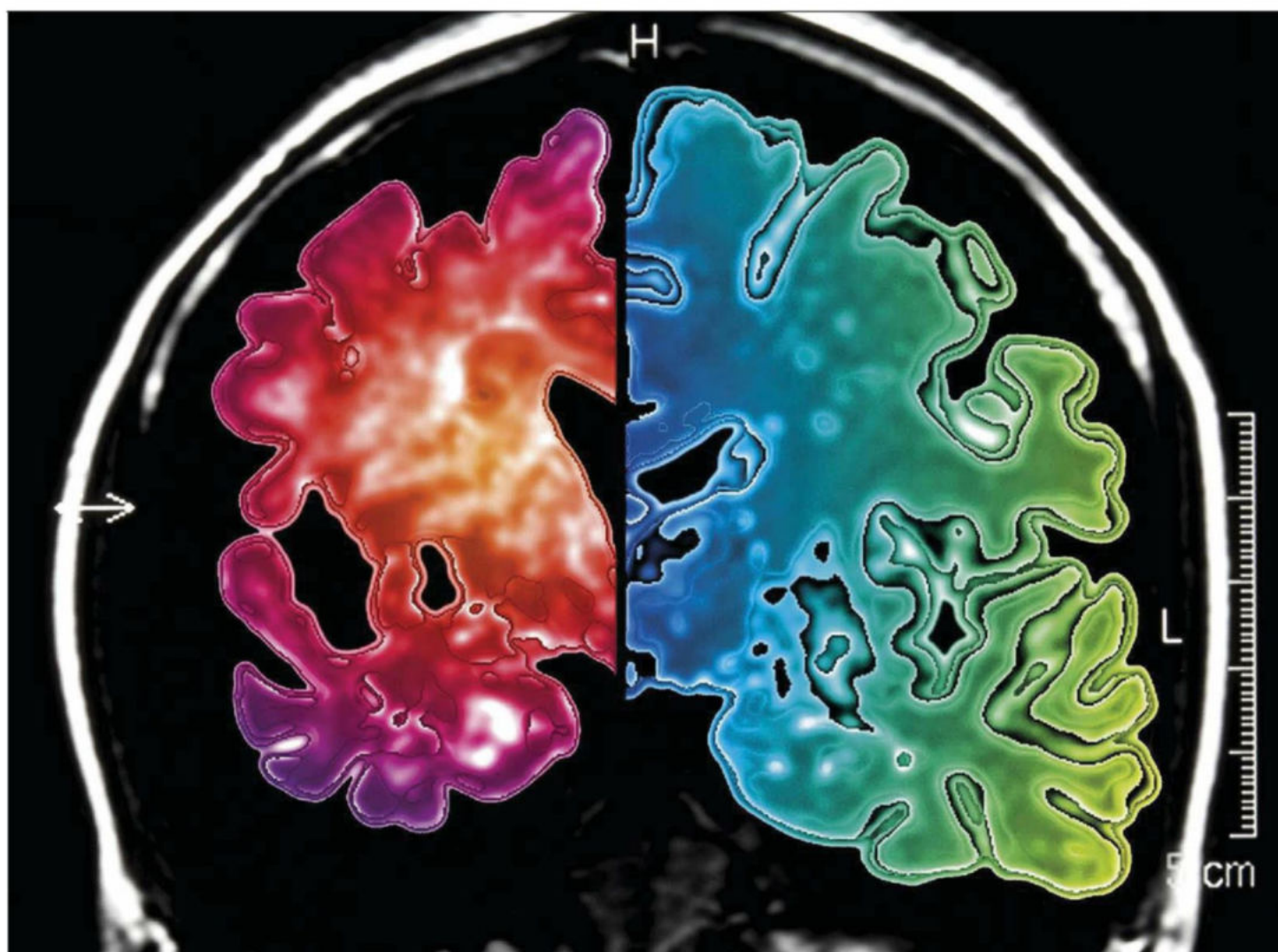
Researchers have found a drug that reduces brain shrinkage,  
prevents cell death and improves memory

Some 850,000 people currently suffer from dementia in the UK. And with this figure set to reach one million by 2025, the scale of the problem facing health services is obvious. Now, researchers at Cambridge University have found that trazodone hydrochloride, a drug already prescribed as an antidepressant, may be able to prevent the brain shrinkage and cell death caused by neurodegenerative diseases such as Alzheimer's disease.

So far the drug has only been tested in mice, but as it has already been approved for human use it could be

fast-tracked into clinical trials. "We know that trazodone is safe to use in humans, so a clinical trial is now possible to test whether the protective effects of the drug we see on brain cells in mice with neurodegeneration also applies to people in the early stages of Alzheimer's disease and other dementias," explained research lead Prof Giovanna Mallucci. "We could know in two to three years whether this approach can slow down disease progression, which would be a very exciting first step in treating these disorders."





In neurodegenerative diseases such as Alzheimer's and Parkinson's, faulty proteins build up in the brain. As these proteins accumulate, a natural defence mechanism 'switches off' the vital production of new proteins. The team previously found a drug that was capable of switching this process back on and halting neurodegeneration, but the drug was toxic to humans.

To search for safe alternatives, they tested 1,040 different compounds, first in *C. elegans*, a worm often used in early drug-screening, and then in mice. In the mice, trazodone hydrochloride consistently prevented the emergence of signs of brain cell damage and reduced brain shrinkage.

"Interestingly, trazodone has been used to treat the symptoms of patients in later stages of dementia, so we know it is safe for this group," said Mallucci. "We now need to find out whether giving the drug to patients at an early stage could help arrest or slow down the disease through its effects on this pathway."

They also found dibenzoylmethane, a compound undergoing trials as an anti-cancer drug, to be effective, though more work is required to determine its safety.

## EXPERT COMMENT

## Dr Mark Dallas

*Mark Dallas, lecturer in cellular and molecular neuroscience, University of Reading*

"This study takes the focus away from tackling disease-specific proteins to restore brain function and points to a global pathway that can be targeted to benefit a range of brain diseases. Encouragingly, treatment with a currently available antidepressant prevented brain cell death in different mouse models of brain disease.

In addition, and of interest to the Alzheimer's community, the authors present evidence that the drug can prevent memory

loss typically seen in a model of dementia in mice.

The study presents a strong scientific basis for this global approach, but it remains to be seen if a single drug can provide widespread benefits for an array of human brain diseases. Indeed, while this antidepressant is ready for human clinical trials, the timing of diagnosis of dementia or Parkinson's and treatment will be critical to the future success of any forthcoming clinical trials."

ABOVE: In this image of an Alzheimer's brain (left) compared with a normal brain (right), the shrinkage is clearly visible



## ZOOLOGY

# NAKED MOLE RATS 'TURN INTO PLANTS' TO SURVIVE IN LOW OXYGEN ENVIRONMENTS

They may not be the most handsome animals in the world, but naked mole rats make up for their unusual looks in other ways: they appear to be immune to cancer, feel little pain and outlive other rodents by years. Now, researchers from the University of Illinois, Chicago have discovered yet another remarkable ability: naked mole rats can survive hours of oxygen deprivation by mimicking the metabolism of plants.

When the brain cells of humans, laboratory mice, and all other known mammals are starved of oxygen, they run out of energy and begin to die. However, naked mole rats have a backup: they are able to switch their brain cells to burn fructose, allowing them to produce energy without the need for oxygen. This is similar to how plants work.

Understanding how the animals do this could lead to treatments for patients suffering

from oxygen deprivation because of heart attacks and strokes.

"The naked mole rat has simply rearranged some basic building-blocks of metabolism to make it super-tolerant to low oxygen conditions," said researcher Prof Thomas Park.

At oxygen levels low enough to kill a human in minutes, the team found naked mole rats were able to survive for at least five hours. Essentially, they go into a state of suspended animation by reducing their movement, and dramatically slowing their pulse and breathing rate. They then begin burning fructose until oxygen is available again.

The naked mole rat is the only known mammal to use suspended animation to survive oxygen deprivation. The researchers think that the animals' unusual metabolism is an adaptation for living in crowded, oxygen-poor burrows.

**Naked mole rats: not that cute, but tougher than you**



## NAKED MOLE RAT FACTS



Naked mole rats are neither moles or rats. They are more closely related to porcupines and guinea pigs.



The rodents are native to the tropical grasslands of East Africa, including Ethiopia, Kenya and Somalia.



They are the longest-lived of all rodents, with a lifespan of more than 30 years.

## 5km

Colonies of naked mole rats can contain as many as 300 individuals with tunnel systems running up to 5km in length.



Their colonies are organised socially in a manner similar to that of ants and wasps. There is a single queen and many soldiers and workers.



## THEY DID WHAT?!

NUTRITIONAL VALUE  
OF HUMAN FLESH  
CALCULATED**What did they do?**

Researchers at Brighton University analysed human flesh to find out its calorie content.

**Why did they do that?**

They wanted to investigate the motivations for past human species engaging in cannibalistic practices. There is currently debate as to whether the consumption of human flesh was for survival, psychotic, spiritual or dietary reasons.

**What did they find?**

A 65kg human has approximately 32,000 calories in their muscle tissue, compared to 163,000 for a deer. This suggests that our ancestors were highly unlikely to hunt and consume members of their own species for strictly nutritional reasons, the researchers say.

## ENTOMOLOGY

WORLD'S OLDEST BEDBUGS  
DISCOVERED IN USA CAVE

This story is likely to make your skin crawl. Human lice have been around for at least 100,000 years, and it is thought that another bloodsucker, the bedbug, is equally ancient. But we have no clear evidence for its early forms. Now, though, bedbugs from 5,000 to 11,000 years ago have been discovered.

According to paleoinsect expert Martin E Adams, who carried out the research, the remains found in a cave system near Paisley in Oregon, USA are not the species of bedbugs that we know from hotel rooms today (*Cimex lectularius* and

*C. hemipterus*). Instead, the three species discovered in the caves (*C. pilosellus*, *C. latipennis*, and *C. antennatus*) preyed only on bats. It is thought that while some *Cimex* species developed a liking for human blood when we lived in caves alongside the flying mammals, these American bugs never made the transition.

Pinning down the reasons why the bugs stuck to a bat diet will be an archaeological challenge. It is possible, Adams suggests, that the Paisley Five Mile Point Caves were never occupied long enough for the





bugs to adapt. The preferences of the bugs may even give an indicator to changes in the US climate. “The presence of warm-tolerant cimicids in the caves, such as *C. antennatus*, may suggest that climatic conditions at Paisley Caves 5,100 years ago were similar to what *C. antennatus* enjoys today in its current range,” said Adams. While the ancient bugs may not have had a taste for human blood, they could prove surprisingly informative about the way our environment has changed.

*Cimex lectularius* is one bedbug species that's developed a taste for human blood



Scientists captured this image of the remains of the explosion

#### SPACE

## COLLIDING STARS CREATE COSMIC FIREWORKS DISPLAY

Talk about starting with a bang! Scientists at the Atacama Large Millimeter Array in the Chilean desert have observed the collision of at least three protostars (one loner and a binary pair) in the Orion Molecular Cloud 1. This vast expanse of gas, 1,350 light-years from Earth, is home to a collection of protostars – infant stars that have yet to properly ignite. Though these bodies are not dense enough to undergo full-scale nuclear fusion, they can radiate in the infrared region because shockwaves are produced as extra material is pulled into the star.

According to lead author John Bally of Colorado University, the collision took place around 1,850 years ago and

sent the Orion Molecular Cloud 1 into explosive turmoil. Bally describes this as “a cosmic version of a Fourth of July fireworks display”. It would take the Sun 100 million years to produce the same energy as this celestial pile-up.

In the explosion, other protostars were flung clear, and great streamers of carbon monoxide gas were blasted away at high speed, stretching over a light-year into space. The fast-moving gas gives off radio waves, which we can pick up at the Atacama Large Millimeter Array.

While there is still plenty to untangle in how this explosive transformation took place, it shows that the cradles of stars can be anything but gentle.





*Diandongosuchus fuyuanensis* lived during the Triassic

#### PALAEONTOLOGY

## NEW CLASSIFICATION OF SEMI-AQUATIC CROCODILE-LIKE DINOSAUR

Palaeontologists cringe at the mention of 'missing links', but they can't deny that the fossil record has plenty of holes. Now there's one less gap, thanks to a fossil find that shows how a group of dinosaurs with a passing resemblance to crocodiles developed.

The semi-aquatic phytosaurs lived between 250 and 200 million years ago. The fossil in question, *Diandongosuchus fuyuanensis*, pre-dates the oldest known phytosaur by around five million years and was originally classified as a poposauroid, a closer relative to crocodiles. That was until Dr Michelle Stocker from Virginia Tech saw a photo of *Diandongosuchus* in a newspaper, and noticed that its bones resembled those of phytosaurs. Stocker and her team went to China,

where the fossil originated, to investigate the bones, leading to its reclassification as a phytosaur.

The relatively small animal has a considerably shorter snout than other phytosaurs, suggesting that longer snouts, ideal for predatory attacks, developed later than researchers had assumed. "So much of our study of the fossil record is about filling in the gaps in our knowledge of how animals came to look as they do or live where they are... we're never done filling in those gaps," said Stocker.

Although we aren't able to watch a phytosaur attack its prey, we can study its very distant cousin, the crocodile. Fossil finds like this help illuminate the transition from the distant past to the more familiar forms of life we know today.

## SPACE

## Atmosphere found around Earth-like planet

So far astronomers have found more than 3,600 extrasolar planets orbiting distant stars, but it has been impossible to tell if the Earth-like planets had an atmosphere. Until now. A team at Keele University has found a planet around 1.4 times the size of Earth that shows clear signs of an atmospheric layer.

Dubbed GJ 1132b, the planet orbits a star around 39 light-years away.

"While this is not the detection of life on another planet, it's an important step in the right direction," said lead astronomer Dr John Southworth.

One of the best potential indicators of life is the make-up of a planet's atmosphere. Earth's oxygen, for example, was almost entirely produced by living organisms.

Detecting GJ 1132b's atmosphere was possible because the 2.2m MPG/ESO telescope at the European Southern

Observatory in La Silla, Chile registers several bands of light wavelength simultaneously. In one band, the planet – detected as it blocked the light of its star – showed up bigger than in the others, suggesting these wavelengths were blocked by an atmosphere.

"With this research, we have taken the first tentative step into studying the atmospheres of smaller, Earth-like planets," said Southworth. "We simulated a range of possible atmospheres for this planet, finding that those rich in water and/or methane would explain the observations."

There is a long way to go before we will find extraterrestrial beings. GJ 1132b is unlikely to be a serious contender for life, as it has a scorching surface temperature of around 370°C. But its discovery moves us closer to the first detection of ET.



Exoplanet GJ 1132b seems to have an atmosphere, as depicted in this illustration

## THE DOWNLOAD

## Masterprints

### What's that? A new high-street print shop?

Way off. It's a digitally composed fingerprint put together by a team at New York University. It can act as a skeleton key to unlock phones equipped with fingerprint sensors.

### How does that work?

Full fingerprints are difficult to falsify, but the scanners found on smartphones are so small that they can only read partial prints. Phones therefore take several photos, with only one match required to unlock the device.

### Tell me more.

Although everyone's fingerprints are unique, they do contain common features. The team studied 8,200 partial fingerprints and found several prints that matched at least 4 per cent of the others. They analysed these 'masterprints' and built an algorithm to create synthetic prints capable of matching many more.

### This sounds worrying. Is my phone safe?

In the lab environment the masterprints matched 26 to 65 per cent of users after five attempts. Still, we'll be keeping a closer eye on our phones from now on.



Fingerprint security may not be as secure as you think



## NATURE

"It's not just the corals we're concerned about, it's the whole ecosystem"

*For the second year in a row, the Great Barrier Reef has suffered from mass coral bleaching. Coral expert Prof Terry Hughes explains why the phenomenon occurs*

#### What is coral bleaching?

Bleaching is a stress response by corals. If you put a coral into an aquarium and the water's too hot or cold, or the salinity isn't right, you make the coral uncomfortable and it will bleach. Bleaching occurs when the relationship between a coral and the microscopic algae that live inside its tissue breaks down. The whiteness is caused by the loss of colourful algae, so you're looking through the animal tissue of the coral host and seeing underlying skeleton.

BELOW: A diver near Australia's Orpheus Island researches bleached coral in March this year



#### Can the animals recover?

Yes. The algae are called 'zooxanthellae' and, after a bleaching event, zooxanthellae that remain alive in the coral tissue grow again and the corals regain their colour. Without zooxanthellae, the animal is nutritionally compromised because the algae photosynthesise and give

energy to the corals. If they don't grow back, the corals starve. Severe bleaching leads to a slow death, but with milder bleaching the algae regrow in time to save the coral.

#### What is mass bleaching?

In the 1980s and 1990s, we began to see the phenomenon of mass coral bleaching at a scale of thousands of kilometres. We've seen three events where 15 to 75 per cent of the world's coral reefs have had huge episodes of bleaching. It's due to global warming.

We've had four events on the Great Barrier Reef. We have records of water temperatures going back to the 1880s, and 1998 had the warmest water on record. That record was broken last year. The other two bleaching events were 2002 and this year. Some reefs bleach, some don't – the footprint of all four events on the Great Barrier Reef is quite distinctive.

#### How did you study the Great Barrier Reef?

The Great Barrier Reef is made up of nearly 3,000 individual reefs. We booked planes and boats, and about 300 researchers were involved. We quantified heat exposure from satellite data and





ABOVE: These corals should be beautiful, bright colours

the amount of bleaching, measured underwater, for about 150 reefs. We produced a map showing the northern, tropical half of Australia. We had back-to-back bleaching, in 2016 and 2017, for the first time. That's significant for two reasons. One is the lack of any recovery time – it takes a decade for even the fastest-growing corals to replace the dead ones. The other issue is the footprints were different. We lost a huge number of corals in the north last year, this year in the central part. So in 12 months, two-thirds of the Great Barrier Reef has been severely bleached.

#### Can the Great Barrier Reef be saved?

I don't want people writing off the Great Barrier Reef, but certainly there's no time to lose. The four events occurred with 1°C of global average warming, but carbon emission scenarios that take us 6°C above pre-industrial temperatures would be catastrophic. The nooks and crannies provided by corals are critically important for most creatures that live on a reef. When coral cover crashes, it affects fish and everything else that needs the habitat provided by coral. Corals are the architects of the reef, they provide the structure. It's like losing the trees in a rainforest. So it's not just the corals we're concerned about, it's the whole ecosystem.



### MANATEES

These marine mammals have been reclassified from endangered to threatened. Numbers in Florida plummeted to just a few hundred in the 1970s but there are now more than 6,600.

### CYCLE COMMUTERS

A study at the University of Glasgow involving almost 265,000 participants has found that going to work by bike greatly reduces your chance of dying from cancer and cardiovascular disease.

Time to squeeze into that Lycra.

### GOOD MONTH

### BAD MONTH

### UNIVERSITY STUDENTS

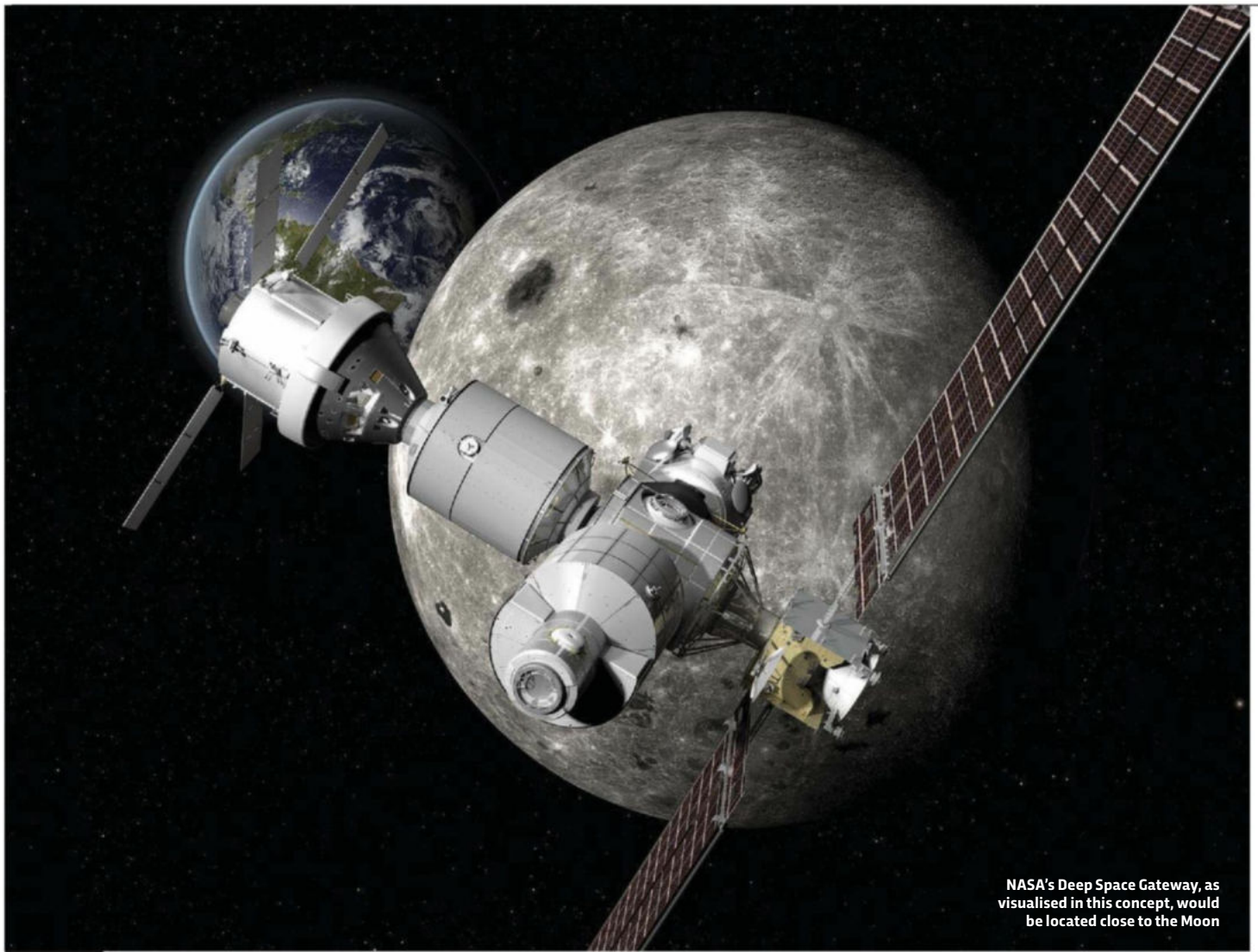
It's not just low beer prices that affect university students' performance in early morning classes. Young adults' body clocks don't allow them to concentrate fully until 11am, researchers at the Open University have found.

### UK PARENTS

Over 29 per cent of UK babies suffer from colic – defined as crying for more than three hours a day for at least three days a week – in the first weeks of their lives, a team at the University of Warwick has found. Only Canadian babies cry more.







NASA's Deep Space Gateway, as visualised in this concept, would be located close to the Moon

SPACE

## NASA'S DEEP SPACE GATEWAY COULD ALLOW ASTRONAUTS TO PREPARE FOR MISSIONS TO MARS

If we are ever going to stage a manned mission to Mars it probably makes sense to have a few trial runs first, right? Enter NASA's Deep Space Gateway – a halfway house that could act as a launching point for missions to the Red Planet and other areas of deep space.

Building a station in the area of space near the Moon would allow us to experience deep space environments while maintaining the ability to return to Earth in matter of days.

NASA plans to build the station during the first few missions of the Space Launch System (SLS) megarocket and Orion crew capsule, which are scheduled to fly together for the first time in late 2018. Deep Space Gateway will consist of three

modules: a power and propulsion system; a habitat module where astronauts will sleep; and a logistics module for research.

Once the station is complete, the agency will begin a programme of one launch per year to research the possibility of deep space exploration.

"I envision different partners, both international and commercial, contributing to the gateway and using it in a variety of ways with a system that can move to different orbits to enable a variety of missions," said NASA's William Gerstenmaier. "The gateway could move to support robotic or partner missions to the surface of the Moon, or to a high lunar orbit to support missions departing from the gateway to other destinations in the Solar System."

## NEUROSCIENCE

# SECRETS OF DREAMING UNCOVERED IN BRAIN SCAN STUDY

Whether it's falling from a great height or going to work without any clothes on, we all have dreams that stick in our minds. Now, researchers at the Wisconsin Institute of Sleep and Consciousness have found tantalising clues of what exactly goes on in our brains when we dream.

The researchers monitored the brain activity of 46 sleeping volunteers using caps linked to 256 electrodes. They found that dreams occurred during both REM and non-REM sleep, and the brain showed high-frequency activity in particular regions according to the content of dreams. For example, dreams associated with hearing speech triggered activity in parts of the brain involved in language perception and understanding.

"This suggests that dreams recruit the same brain regions as experiences in wakefulness for specific contents," said researcher Francesca Siclari. "This also indicates that dreams are experiences that truly occur during

wakefulness, and that they are not 'inventions' or 'confabulations' that we make up while we wake up."

The researchers also found that dreaming was linked to activity in a 'hot zone' found in the back of the brain, regardless of which stage of sleep the volunteers were in. The study also shows that dreams may be a valuable model for studying consciousness, they said.

"Dreams are forms of consciousness that occur during sleep. In the course of a night's sleep, consciousness varies considerably: it can either be absent or present in the form of thoughts, images or dreams," said researcher Giulio Tononi. "An important aspect of this study is that we were able to compare what changes in the brain when we are conscious, that is, when we are dreaming, compared with when we are unconscious, during the same behavioural state of sleep. In this way we could zoom in on the brain regions that truly matter for consciousness."



Activity in a 'hot zone' in the brain shows when someone is dreaming

## IN NUMBERS

## 750,000

The number of pieces of space debris larger than 1cm in diameter orbiting the Earth, as reported by the European Space Agency.

## 1 IN 1.6 TRILLION

The odds that the thylacine (Tasmanian tiger) still exists, as calculated by mathematicians at the University of California, Berkeley.

## 75 PER CENT

The proportion of sea creatures living up to 4,000m below the surface that glow in the dark, as found by researchers at the Monterey Bay Aquarium Research Institute.



## WHAT WE LEARNED THIS MONTH

### CHIMPS DON'T APPRECIATE MUSIC

Sorry, fans of *The Jungle Book*, apes aren't musical. Researchers in York have found that music, be it Beethoven or Bieber, has no positive effect on captive chimpanzees' welfare. The research echoes an earlier study that found orangutans are unable to distinguish music from white noise.

### TALLEST HUMANS ARE DESCENDED FROM MAMMOTH HUNTERS

Standing at an average of six feet tall, men from the Netherlands, Montenegro and Denmark are the tallest in the world. Their lofty stature is likely due to their ancestors consuming nutritionally rich mammoth meat, a team at the Czech Republic's Masaryk University has found.

### OCEAN CURRENTS ARE CARRYING BILLIONS OF PIECES OF PLASTIC TO THE ARCTIC

Researchers at Cadiz University, Spain have found two major 'dead ends' in the Greenland and Barents Seas, into which ocean currents are dumping vast amounts of plastic waste.

## EVOLUTION

# THE MOST ANCIENT ANIMALS ON EARTH MAY BE COMB JELLIES

Did your billion-times great grandfather look something like this eerie bag of jelly? Evolutionary biologists at Vanderbilt University in Nashville certainly think so.

The researchers compared the individual genes of comb jellies with those of 18 other organisms, as part of a technique dubbed 'phylogenetics'. The team determined that comb jellies have more genes supporting their claim to be the first animal to diverge than sponges. Sponges were previously thought to be the earliest form of animal life, due to their simplicity.

"In these analyses, we only use genes that are shared across all organisms," researcher Prof Antonis Rokas explained.

"The trick is to examine the gene sequences from different organisms to figure out who they identify as their closest relatives. When you look at a particular gene in an organism, let's call it A, we ask if it is most closely related to its counterpart in organism B? Or to its counterpart in organism C? And by how much?"

The finding could have a major impact on scientists' thinking about how the nervous system, digestive tract and other basic organs in modern animals evolved. "We believe that our approach can help resolve many of these long-standing controversies and raise the game of phylogenetic reconstruction to a new level," Rokas said.

Comb jellies are so-named because of the rows of comb-like plates that they use to propel themselves through the water

PHOTO: GETTY



# HOW AFRICA IS LEARNING TO COPE WITH DROUGHT

*New technologies are helping Ethiopians to stave off famine*

Desperate for some good news during these dark times? Then look no further than drought-stricken Ethiopia, currently in the grip of what looks like devastating climate change. Yes, really.

The Horn of Africa suffers major droughts so often that even aid organisations concede it's hard not to just tune it all out. The rains have failed repeatedly in recent years, with 2011 being the region's worst drought in 60 years. And where there is drought, there is always famine – and death on an appalling scale.

At least, that's the story trotted out ever since the drought in Ethiopia that prompted the famous Band Aid concerts of the early 1980s.

Yet virtually all of it is either simplistic or flat wrong. The idea that the Horn of Africa provides a shocking insight into global warming ignores history. Records show this region experiences at least half a dozen severe droughts each century.

The principal cause appears to be a natural climate cycle similar to the notorious El Niño effect of the Pacific Ocean. Known as the Indian Ocean Dipole, it periodically affects the winds and rains sweeping across the region, triggering drought.

While the frequency of severe droughts does appear to be increasing, attempts to link them to human-made global warming are fraught with uncertainty. It may seem obvious that a hotter planet is drier, but the regional reality is more complex.

The yet more obvious link between drought, famine and death is, ironically, the weakest of the lot. While routinely blamed on drought, the famines that strike the Horn of Africa are no longer seen as inescapable. As Mark Goldring, chief executive of Oxfam, recently put it: "A famine is always the result of either political choices or catastrophic human failure".

Hang on – that doesn't sound like the usual story of humans powerless in the face of natural catastrophe. It almost sounds like victim-blaming. But Goldring's stark statement is backed by a wealth of evidence. Ways of stopping droughts turning into

**"THE IDEA THAT THE HORN OF AFRICA PROVIDES A SHOCKING INSIGHT INTO GLOBAL WARMING IGNORES HISTORY"**

famines, by using crop selection, irrigation and the like, have been known for millennia. The trouble is, applying them demands stable societies and political will.

The Nobel Prize-winning economist Amartya Sen, among others, has pointed out that stable democracies avoid drought-driven famines because their governments know they must either act, or face revolt.


When the Dust Bowl struck America in the 1930s, the Roosevelt administration introduced a host of infrastructure and agricultural measures to prevent a recurrence. When drought struck an even bigger area in the 1950s, the impact was negligible.

India, the world's largest democracy, is routinely hit by droughts, yet similar action over the decades has averted the famines that are all too familiar in the Horn of Africa.

But now it seems there are reasons for hope there too. Ethiopia is suffering a terrible drought, but there is little talk of famine. Instead, officials at the World Food Programme, the UN and even Oxfam are lining up to praise the response of Ethiopia's government. From planting more drought-resistant crops to the use of satellites to guide farmers to better pasture, Ethiopia is

turning into case study of how humans can cope with the vagaries of climate change.

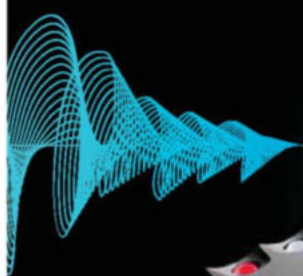
It comes at a time of declining political interest among rich nations in tackling global warming. That's because their voters are now demanding action on clear and present environmental dangers, rather than global threats decades into the future.

Chances are the people of Ethiopia feel the same way. And they'd probably prefer we gave aid to help them adapt to climate change, rather than lavish billions on grand plans to prevent it. 

**Robert Matthews** is visiting professor in science at Aston University, Birmingham.







# NEXT-GEN MUSIC

WE'RE IN THE MIDST OF A DIGITAL AUDIO REVOLUTION  
AND CHORD ELECTRONICS IS AT THE FOREFRONT

Getting the best sound quality from your favourite music, wherever it's stored, is now easier than ever. From CD collections to audio streaming services delivered via the internet, cherished tracks, playlists and albums can now be delivered with sound performance right up to studio-grade-quality.

Not too long ago, that idea would have seemed impossible, but audio tech is accelerating at a baffling pace - helped in no small part by the engineering expertise of British companies like Kent-based Chord Electronics. With a reputation built on crafting hardware for national and international studios, as well as the Royal Opera House, Chord has come to dominate digital audio in recent years.

The company's unique offerings have won countless awards for innovation and performance, and its trickle-down philosophy has allowed it to bring a range of compact, affordable products to music lovers and gadget fans across the globe.

Chord's latest offering is the Hugo 2, a compact amplifier and digital-to-analogue converter (DAC) that connects smart devices, PCs, gaming consoles and virtually anything with a digital output to headphones and existing home audio systems. Hugo 2's hardware and custom software lets you play your music from everyday devices at the highest of standards, regardless of file type. Even the most basic of MP3 files will sound dramatically better.

## HUGO 2 HEADPHONE AMP/DAC

Dramatically improves digital music sound quality

Designed for home and travel use

Connects to headphones and home systems

Connect via USB, Bluetooth, or coaxial and optical

Fast-charge batteries: 7hrs playback from 4hr charge

Low distortion and vanishingly low noise

High-resolution audio compatible (to studio-grade)

British engineering with proprietary soft/hardware

Beneath its precision-machined aircraft-grade aluminium chassis lies an enormously powerful processor, custom-coded with unique software that processes and filters audio with unrivalled precision, accuracy and fidelity. Built to last, Hugo 2 brings your music right up to 2017 standards.

Chord's extensive UK dealer network means you can try before you buy and hear the benefits of Chord's unique technology for yourself. Head to the site address below and find your nearest dealer today.



DESIGNED AND  
MADE IN THE UK

## Hugo<sub>2</sub>

@ChordAudio

facebook.com/chordelectronics

chordelectronics.co.uk

# INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

JUNE 2017

EDITED BY RUSSELL DEEKS



The shoes are 15 per cent lighter than one made with traditional polymers

## SPIDER FEET

Adidas has woven its newest shoes out of synthetic spider silk. This 'biosteel' is a product of bacteria, genetically modified to produce a silk-like substrate, which is spun into thread. Though they won't let you walk

up walls, these trainers are fully biodegradable. In fact, Adidas will supply the trainers with a solution that'll safely dissolve your shoes in a couple of hours.

*Adidas Futurecraft Fabric, ETBC, [adidas.com](https://adidas.com)*



1



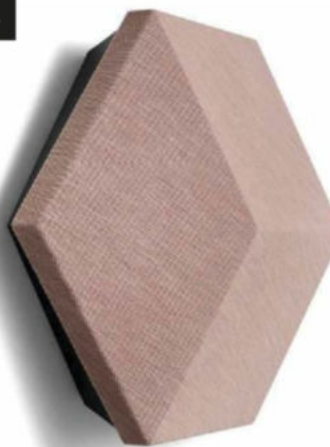
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3



4



5



## WANTED

1

### BACKPACK WARRIOR

This rucksack is a gadget lover's dream, with a Qi wireless charging pocket, an RFID-blocking pocket, and compartments for your laptop, tablet, audio player and cables. There's Bluetooth tracking built-in, and it's waterproof, too.

**Knomo #LiveFree Backpack,**  
£270, [knomobags.com](http://knomobags.com)

2

### CLEANER CANINES

Bissell makes vacuum cleaners and carpet shampooers, but now it's created a wet-and-dry vacuum for dogs that'll let you wash your pet wherever you are. It uses 50 times less water than standard bathing, creating considerably less mess.

**Bissell BarkBath,**  
\$149.99, [bissell.com](http://bissell.com)

3

### CORD CUTTERS

Renowned guitar amp maker Marshall got into the headphones game a few years ago, and the latest addition to its line-up is this wireless version of its Monitor headphones, with 40mm custom drivers and 30 hours of playback.

**Marshall Monitor Bluetooth,**  
£219, [marshallheadphones.com](http://marshallheadphones.com)

4

### 3D SOUND

What you see in this picture isn't a fancy piece of wall art but rather Bang & Olufsen's latest modular speaker system. It offers Bluetooth, AirPlay and Chromecast streaming, and is compatible with B&O's multi-room systems.

**Bang & Olufsen BeoSound Shape,**  
From £3,400, [bang-olufsen.com](http://bang-olufsen.com)

5

### TIME TO CONNECT

Movado's first Android Wear smartwatch is compatible with all Wear 2.0 apps, Android Pay and Google Assistant, and gives you a choice of 100 different watch faces, all featuring Movado's iconic single-dot design.

**Movado Connect,**  
£TBC, [movado.co.uk](http://movado.co.uk)

6

### BLUMENTHAL MARVELLOUS

Designed by chef Heston Blumenthal, this range of barbecue grills features a hybrid charcoal-electric ignition system for faster, safer, chemical-free lighting and, on the larger models, an integrated rotisserie system.

**Everdure by Heston Blumenthal,**  
£149-£1,499, [everdure.com](http://everdure.com)

6





# THE SOUND OF SUMMER

Hi-fi expert **Verity Burns** finds out which Bluetooth speaker is tough enough to survive the British summer...

## ALTEC LANSING BOOMJACKET

There's little you could throw at the Boomjacket that it wouldn't take in its stride. It's been designed for the Great Outdoors, with mounting gear in the box for securing to your bike or kayak and a mega 40-hour battery life. Even its sound is tuned for purpose, with a crisp, forward presentation that's loud enough to be heard above the chaos. It's a little congested at volume, but such critical listening isn't always top priority when you're hurtling down the side of a mountain. **8/10**

£129.99, [alteclansing.com](http://alteclansing.com)



## JBL FLIP 4

JBL has been giving its rivals some healthy competition for a while now, and the fourth generation of the popular Flip speaker sounds better than ever. The Flip is tough and waterproof (but it will sink, so act fast if you drop it in the pool), and is a brilliant portable party speaker with a surprising amount of bass for its size. It comes in six vibrant colours and packs JBL Connect+ too, meaning you can daisy chain over 100 (!) compatible JBL speakers for a more powerful performance. **9/10**

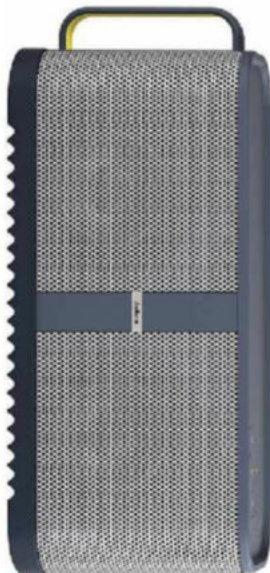
£119.99, [uk.jbl.com](http://uk.jbl.com)



## JABRA SOLEMATE MAX

Somewhere between super portable and the Monster (see right) sits Jabra's Solemate Max. It makes rugged look good, mixing textured rubber bumpers with sturdy metal grilles, and a carry handle for easy portability. Its handy, if slightly cheesy, voice commands make it easy to get your device paired, plus you can get audio updates on its battery level. We just wish the sound was a little cleaner sounding at volume. Flip it over and you'll find a 3.5mm cable hidden in the base. **7/10**

£249.99, [jabra.co.uk](http://jabra.co.uk)



## MONSTER BLASTER

At almost 8kg, the Monster Blaster pushes the boundaries of what can be considered portable. Nonetheless its carry handle and boombox style make it easy enough to move into your garden or car without too much effort. Still, it's worth it – this big and powerful-looking speaker churns out big and powerful sound too, but it's surprisingly refined at the same time. Take it to the park and expect to gain as many friends as you do foes – the Blaster will drown out anything around it. **8/10**

£349.95, [monsterproducts.eu](http://monsterproducts.eu)

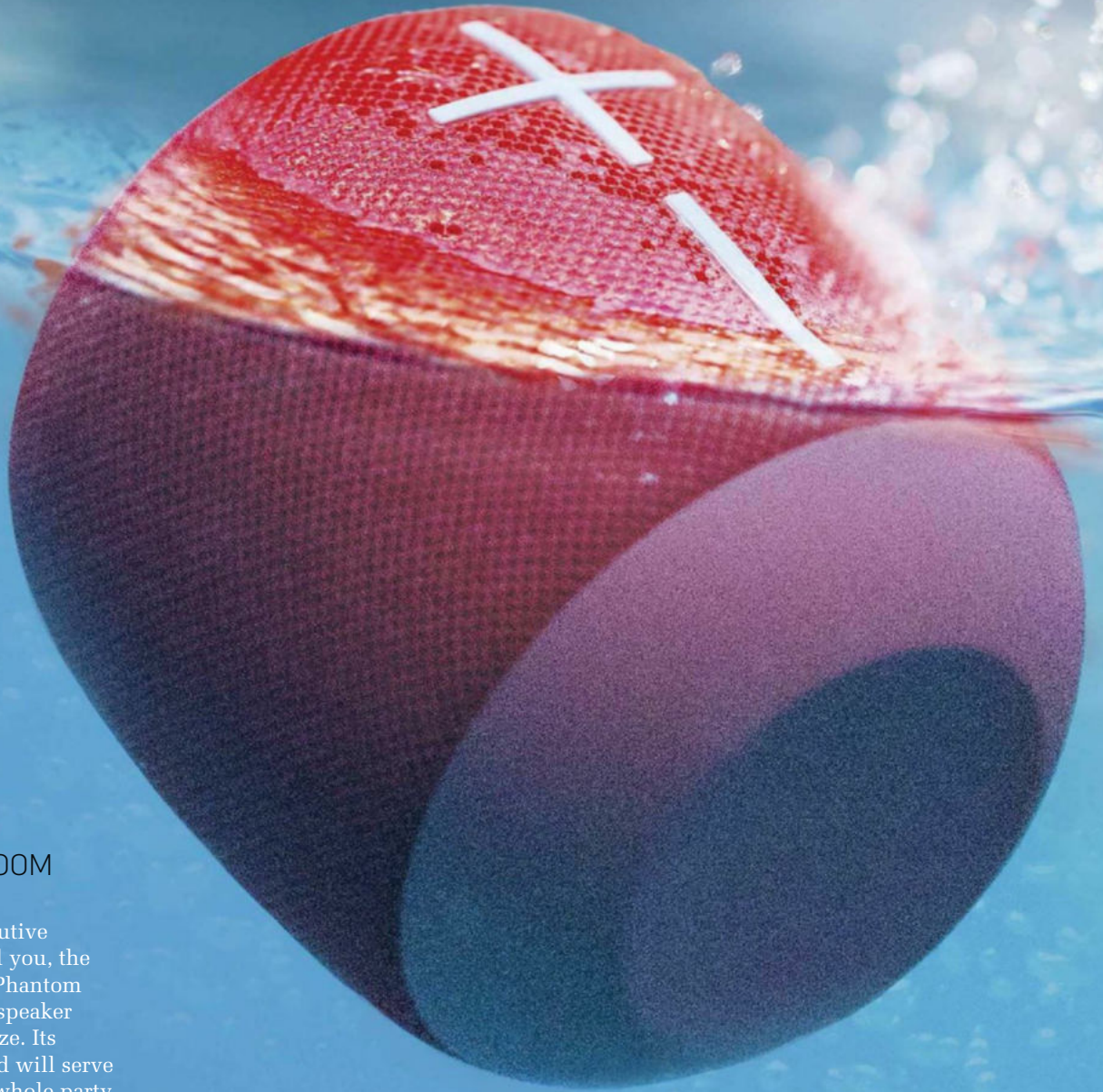


## TOUGH ENOUGH?

To find out how tough a speaker really is, look at its IP rating. The first number represents its dustproof capability, up to 6 (X is used when no official rating is known), and the second number shows its level of waterproofing, up to 8. The higher the number, the better the protection.

## SPEAKER SPECIFICATIONS

SPEAKER	IP RATING	DIMENSIONS (H x W x D)	WEIGHT	BATTERY LIFE	3.5mm INPUT	NFC?
UE Wonderboom	IP67	102 x 140 x 94mm	425g	10hrs	No	No
Altec Lansing Boomjacket	IP67	76 x 197 x 76mm	907g	40hrs	Yes	Yes
JBL Flip4	IPX7	68 x 175 x 70mm	515g	12hrs	Yes	No
Jabra Solemate Max	Unknown	138 x 302 x 102mm	3kg	14hrs	Yes	Yes
Monster Blaster	IPX5	203 x 457 x 203mm	7.65kg	8hrs	Yes	Yes



## UE WONDERBOOM PHANTOM

Don't let its diminutive measurements fool you, the UE Wonderboom Phantom gives as good as a speaker several times its size. Its punchy 360° sound will serve up sound to your whole party wherever it's placed, and its dinky dimensions mean it's an easy choice for throwing in your bag wherever you go. It's a tough cookie too, surviving drops from 1.5m, and floating in water for up to 30 minutes. Bold by nature, bold by design – you'll be hard pushed to find better under £100. **10/10**

**£89.99, [ultimateears.com](https://ultimateears.com)**



# WATCH OUT

Finally, the Apple Watch might have a high-end rival. **Daniel Bennett** tests the Tag Heuer Connected Modular 45 to find out if the Swiss are ready for the digital crossover...

## PRICE

From £1,200

[tagheuer.com](http://tagheuer.com)

## SPECIFICATIONS

**AMOLED** capacitive touchscreen, 16M colours

**Display size:** 3.53cm

**Resolution:** 400 x 400 pixels (~287 ppi pixel density)

**Multitouch:** Yes

**Protection:** Sapphire crystal glass

**WLAN:** Wi-Fi 802.11 b/g/n

**Bluetooth:** 4.1, LE



## DESIGN

Over the years, Tag Heuer has obviously worked out how to make a handsome watch, but this wristwatch's biggest selling point is that you can customise it for yourself. Between the strap, dial and movement the Swiss watchmaker says there are up to 56 looks you can create, with more to come. That's before you even start customising its digital face. The only downside is the watch's undeniable heft, which at 13.75mm thick will make even the most trunk-like wrists look twiggy. The AMOLED screen is remarkably bright and sharp: it feels pristine. Anything less and the customisable displays — where you can choose from some of Tag Heuer's back catalogue of faces — would feel like a gimmick.

## HARDWARE

The Modular 45 is crammed with almost everything you could want in a smartwatch. There's a mic for commanding Google Voice, built-in GPS for tracking your runs, and NFC for contactless payment. The chipset making the whole thing tick is the kind you'd usually find powering a smartphone, and the device is waterproof. Heart rate sensors are absent, but this isn't a watch I'd wear on a jog. The display is one of the best we've seen, although it doesn't quite run from edge to edge. The Tag Heuer kit is first-class, as you'd expect, but all that fancy tech comes at a price. As mentioned above the watch is a bit bulky, and the battery will only last you a day — even less if you're making use of the GPS.



## SOFTWARE

The Connected Modular 45 works well with both Android and iOS devices. The watch runs Android Wear 2.0 out of the box, which right now is a rarity. This means you'll be able to download the latest designs and apps direct to your watch from the Google Play Store, so you can enjoy a more user-friendly messaging system and the newest apps. It also means you can sync whatever fitness app you're already using (as long as it's Android Wear compatible) into the watch's GPS. But our favourite bit of software is the face customisation. You can choose from some Tag Heuer classics, or tailor each element to your mood. In our month with the watch, the novelty didn't wear off.



**VERDICT**

This is arguably one of the best smartwatches we've tested. Its design and hardware tick all the boxes, but the reality of its all-too-brief battery life is a sharp reminder of why I don't use a smartwatch in the first place. Ultimately it's a worthy alternative to the Apple Watch, but perhaps not enough to convince us to jump on the smartwatch bandwagon. **8/10**





## CARS

## McLaren now 3D-printing F1 parts

The recent Bahrain Grand Prix saw the McLaren team bringing something new to the pit stop: 3D printing.

Formula 1 teams tweak car and engine component specifications all the time, but it usually takes a little while before a new part – a wider fuel line, say, or a lower-profile front spoiler – is ready for use in a race. To speed up the process, the McLaren team took a Stratasys uPrint SE Plus 3D printer with them to the track, which can produce race-ready parts during the competitive weekend. The printer could even be used to create one-off tools designed to fix unique

problems. It is hoped that, using this technology, design tweaks can be implemented faster than has previously been possible.

Neil Oatley, design and development director at McLaren Racing, said: “We are consistently modifying and improving our Formula 1 car designs, so the ability to test new designs quickly is critical. If we can bring new developments to the car one race earlier – going from new idea to new part in only a few days – this will be a key factor in making the McLaren MCL32 [McLaren’s current F1 car] more competitive.”

ABOVE:  
McLaren MCL32:  
now available  
with 3D-printed  
parts

## PLANES

## Next-generation aviation

Short-haul flights that are up to 80 per cent cheaper and 80 per cent faster sound too good to be true; factor in an 80 per cent reduction in carbon emissions, too, and we're clearly in cloud cuckoo land!

Except Boeing clearly doesn't think so, because along with US domestic airline JetBlue it has just pumped significant amounts of cash into Zunum Aero, a three-year-old start-up that promises its hybrid electric-kerosene aero engines will offer all of the advantages listed above. The company is currently working with the US Federal Aviation Authority and hopes its planes will be certified for operation in the US by the end of next

year, with a view to providing domestic flights within five years. Early versions of the planes will have a range of 1,125km (700 miles), but Zunum hopes to have planes with a range of 1,600km (1,000 miles) built by 2030.

Zunum Aero CEO Ashish Kumar said: "The shift of the industry to large aircraft and gas turbines has concentrated almost all air traffic to just 2 per cent of our airports, creating a massive transport gap over regional distances. Hybrid propulsion is an industry-changing solution, enabling mid-sized aircraft on regional routes to have better cost efficiencies than airliners."



Zunum's planes could offer more efficient short-haul flights

## TECH BYTES

### FASTER BANKING

The UK's Cheque & Credit Clearing Company has started implementing an industry-wide, high-res, secure imaging system that will negate the need for banks to physically send cheques for clearing – meaning that cheques will soon clear in 24 hours rather than 72.



### FLYING SQUAD

Devon And Cornwall Police is setting up a 'drone squad' that will operate on a 24/7 basis. The squad is the first of its kind in the UK and will use drones to monitor road traffic accidents and search for missing persons.

### SECURITY IS WRITTEN IN YOUR PALMS

Fujitsu is developing a biometric identification system based on the unique pattern of veins in your hand. 'PalmSecure' is said to be more accurate than fingerprint or voice identification, and Fujitsu is already working on embedding the tech into its next-generation PCs.



# REPLY

Your opinions on science, technology and *BBC Focus*

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Fairfax Street, Bristol, BS1 3BN

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## MESSAGE OF THE MONTH

### When pigs fly

In reference to the Innovations section of the March issue, I would like to point out that the scenario of UAVs flying low over traffic will not happen in this country due to the already strict operating rules that every responsible RC pilot adheres to and has done since the hobby began!

While there is a huge knee-jerk reaction going on at the moment with regards to legislation in this area, people have been flying responsibly for decades without serious incident. This is thanks in a great deal to common sense, which would suggest that flying anything that close to people and vehicles is a bad idea. I would hope that we still have common sense and do not adopt and apply rules and attitudes just because "they did it"!

**Matt Pearson** (pilot of remote-controlled fixed and rotary wing, including multirotors)

👍 I agree – driving at rush hour is hairy enough, without having to deal with UAVs hovering over your head! – **Ed**



### WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins **bundle of five fantastic science books**. Included in the package is *Bee Quest*; *The Knowledge: Stargazing*; *Visions Of Numberland*; *Lab Girl* and *Deviate: The Science Of Seeing Differently*.

WORTH  
£66

### Better vetting

Regarding reader Gary Sansom in issue 307, I would advise him not to pursue a career in veterinary anaesthesia and critical care. Your pets do not "end up in the skip", they are kept in cold storage and cremated with other pets or individually, then returned as the client sees fit. The editor may comment on his own lack of bedside manner, but Mr Sansom is certainly lacking in dog-bedside manner!

**Miss Hunter** (BVSc, MRCVS)

### Training up

Over a period of five weeks, up until 12 February 2015, trains running on lithium ferrous phosphate batteries were successfully trialled on the route between Harwich and Manningtree. Hot sodium salt batteries were ruled out as they were too bulky.

Regarding the column on batteries by Prof Robert Matthews (May, p23), I would like to ask him a question. Is it fair to assume that sodium batteries, which charge faster than lithium and are not prone to explode, could be used to power 21st-Century trains such as HS2 that are unlikely to be in service before 2027, instead of using the "proved



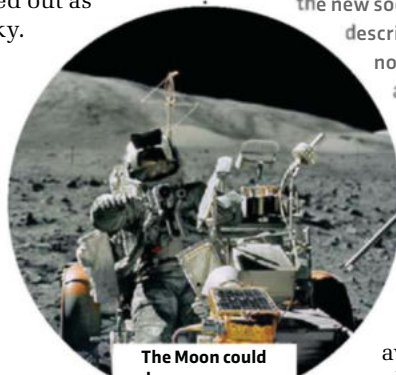
and tested 19th-Century technology" that is currently proposed? Millions of pounds could be saved on installation and the UK could win contracts to build these new trains.

**R Stather, Bromsgrove**

👍 Given the very long lead-times typically seen with new battery types, I suspect that the new sodium batteries described in the article will not be commercially available in time to affect the HS2 project. – **Robert Matthews, science consultant**

### Mooning over money

I am, and have always been, an avid *BBC Focus* reader. However, I was hugely disappointed with the article on going back to the Moon (April, p38). The main reason being that not even one of the contributing authors tackled the most crucial matter: namely



The Moon could make us money, says **Zareh Bedrossian**

the commercial benefits resulting from going to the Moon. I cannot even start remunerating the benefits as my reply would be ridiculously enormous.

Zareh Bedrossian, Beirut, Lebanon

➔ You're right. Money makes the world (and presumably the Moon) go round. However, we had previously covered the gold buried in 'them thar hills' in an earlier issue and wanted to explore some of the philosophical and scientific rewards of a return mission. – Ed

### Time crime

Well, I'm surprised. A leading science magazine with articles about black holes, the fourth dimension and a guide to the cosmos, and yet you think that the Earth rotates on its axis, relative to the Sun, twice in 24 hours. Well, it will have to for the sundial on the cover of your May issue to work.

Of course, I'm assuming the sundial is on Earth. If so, it must be in the northern hemisphere as the numerals are displayed clockwise – they would be anticlockwise south of the equator. The angle between the dial plate and the gnomon [the part of the sundial that casts a shadow] is the same as the latitude of its location – in this case it looks to be in a temperate zone. So you would expect there to be a

period of darkness, and it is generally accepted that it is not worth putting numerals where they are never used.

If you look at a properly designed sundial, you will find that the 6am and 6pm markers are at either end of a line oriented due east to west and passes through the point where the gnomon meets the dial plate.

Mike Shaw, newsletter editor, British Sundial Society

➔ Interesting points! Though I think on this occasion we can claim artistic licence – and would like to point out that the sundial was in space! – Ed

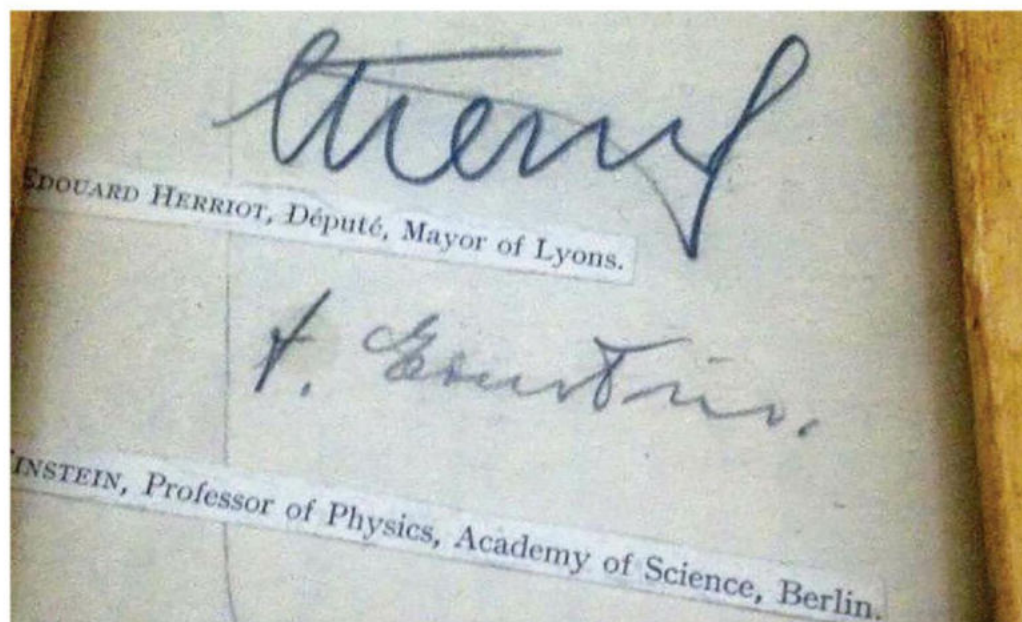
JOIN US ON TWITTER... @sciencefocus

Responding to our article 'Do social networks make us antisocial?', @Pep\_Linden shared his woes: "I set up an antisocial network...but nobody joined..."

@stevesplan spotted one of our favourite pics in the May issue: "The panda guy pic on p57 looks like a scene in a slasher movie. Hilarious."

On the 62nd anniversary of Einstein's death on 18 April 1955, @rich\_14, shared this photo of his grandfather's honorary degree signed by the man himself...

Twitter user @rich\_14's grandfather bagged Einstein's signature!



## FOCUS

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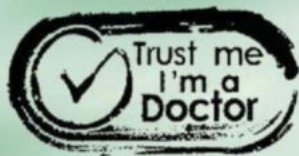
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# IS ANYTHING GOOD FOR YOU ANY MORE?

WORDS: Dr Saleyha Ahsan  
and Dr Michael Mosley



The world of food is full of conflicting advice. Drinking coffee is good for you; it will give you cancer. Eggs are part of nature's natural bounty; they raise your cholesterol. So many claims, so little agreement. Yet despite the headlines there is a fairly consistent body of research that points at the health benefits, or otherwise, of most popular foods. We're here to sort the facts from the fads. Enjoy!

ILLUSTRATION: MAGIC TORCH





## COFFEE

There have been numerous claims over the years that drinking coffee will increase your risk of succumbing to a whole range of terrible things. Yet when scientists followed over 120,000 men and women for more than 20 years they found something altogether more surprising. The study, *The Relationship Of Coffee Consumption With Mortality*, concluded that “regular coffee consumption was not associated with an increased mortality rate in either men or women”. In fact, they found moderate coffee consumption appears to be mildly protective. Based on this and other studies, the most effective ‘dose’ seems to be two to five cups a day. More than that and any benefits drop off. But we simply don’t know what it is in coffee that helps.

The amount of coffee you can safely drink without side effects, such as a temporary rise in blood pressure or insomnia, may be down to your genes, and in particular how much of the liver enzyme CYP1A2 you have. CYP1A2 helps determine the speed at which caffeine is cleared from your body. This could explain why I can drink coffee in the evening with no problems, while one cup in the afternoon has my wife twitching. – MM

**VERDICT:** *Two to five cups of coffee a day are fine, but side effects may be dictated by your genes.*





There's  
little evidence  
that diet soft  
drinks actually help  
people **lose**  
**weight**

## DIET DRINKS

I'm teetotal, so on a night out mine is a diet soft drink of some sort. But even though the label on the bottle says sugar-free, research suggests I shouldn't be fooled into thinking it's any better for my waistline than a standard version. Health commentators argue there is little evidence that 'diet drinks' containing artificial sweeteners actually help people lose weight and therefore should not be recommended as part of a healthy diet. In fact, many existing systematic reviews promoting the health benefits of diet drinks are sponsored by the soft drinks industry itself, and are hence unreliable.

According to a recent review by Imperial College London, these diet drinks stimulate sweet taste receptors, potentially encouraging us to eat food as compensation. Psychologically, we might be more inclined to treat ourselves to something unhealthy, as we've had a 'good' low-calorie drink. I can vouch for that one.

When it comes to drinking standard drinks versus a diet drink, I still opt for diet. If I'm serious about making the best choice, I'll opt for water – although I have been known to order a cup of tea on a night out! – **SA**

**VERDICT:** *Stick to water rather than soft drinks and your body (and wallet!) will thank you.*

---

## ALCOHOL

You can't open a newspaper without reading a story about alcohol being good or bad for you, or making no difference at all to your health. So what's the truth? Well, if you like the odd tipple, there is some good news.

Though it has been challenged, there is a fairly consistent body of evidence that drinking modest amounts of alcohol may protect you against heart disease. A recent study, which was published in the *European Heart Journal*, followed more than 14,000 adults aged 45 and older for 24 years and found that men and women who reported drinking up to 12 units of alcohol per week (the equivalent of around six glasses of wine) had a lower risk of developing heart failure than those who never drank. They also found that those most likely to have died from any cause over the course of the study had been heavier drinkers, where women were drinking more than 14 units and men were drinking more than 21 units a week. Cheers! – **MM**

**VERDICT:** *Enjoy up to six glasses of wine a week to potentially reduce your risk of heart failure. Any more could be hazardous to health.*

## EGGS

A few years ago we were being told by nutritionists not to eat more than a few eggs a week on the grounds that eggs contain cholesterol and cholesterol is bad for you. At the time, it was widely believed that elevated cholesterol in our blood is caused by cholesterol in our food. In fact, most of the excess cholesterol in our blood is produced by the liver and is a response to eating too much saturated fat. A meta-analysis of 17 studies published in the *BMJ* in 2013 concluded that "higher consumption of eggs is *not* associated with increased risk of coronary heart disease or stroke". Whether scrambled, boiled or poached, eggs are a superb source of protein, are rich in vitamins and minerals and make a great start to the day. How do you like yours? – **MM**

**VERDICT:** *As long as you're not frying them or smothering them in fat, eggs are an excellent breakfast choice.*





## RED MEAT

Do you walk round the shops thinking about what to slap on the barbecue, pause by the steaks, pick them up, put them back and then go in search of something healthier? In a restaurant do you order fish, even though you'd secretly prefer lamb?

If you believe the headlines, then eating meat will stop your heart, give you cancer, shorten your life and destroy the planet. The meat which is said to be a threat to health is red meat like steak, lamb, pork and mince. Red meat looks darker thanks to higher levels of haemoglobin and myoglobin, which are the iron- and oxygen-binding proteins you find in blood and muscle.

On the upside, red meat is an excellent source of micronutrients. But on the downside, it's richer in saturated fat than, say, tofu. It has also been linked to an increased risk of bowel cancer. But overall just how bad for you is red meat?

One recent paper, *Meat Consumption And Mortality* tried to answer that question. It came to the – perhaps surprising – conclusion that eating moderate amounts of red meat had no effect on mortality, in fact it seemed to be protective. The lowest overall mortality rates in this study were among those people eating up to 80g a day, not those who shunned it. This particular paper was based on findings from the European Prospective Investigation into Cancer and Nutrition (EPIC). In this study, European researchers followed more than half a million people in 10 countries for more than 12 years.

The researchers found that although there was a small increase in overall risk for those who ate over 160g a day, there was also a higher death rate among people who ate no meat at all. They concluded that “a low – but not a zero – consumption of meat might be beneficial for health. This is understandable as meat is an important source of nutrients, such as protein, iron, zinc, several B-vitamins, as well as vitamin A and essential fatty acids”. In other words, vegans and vegetarians may not have been getting sufficient essential micronutrients.

Now before meat eaters go off rejoicing, there's a significant sting in the tail. The EPIC study found that eating processed meat, like sausages, bacon and ham, *did* have a negative effect on health. Over 40g a day (fewer than two slices of bacon) and deaths from heart disease and cancer began to climb. “In this population, reduction of processed meat consumption to less than 20g/day would prevent more than 3 per cent of all deaths,” it said. – *MM*

**VERDICT:** *Small amounts of red meat are fine, but keep the processed stuff as an occasional treat.*







## SALT

Most of us know too much salt is bad for us. What's less well-known is that too little is also harmful. We need salt for muscle and nerve activity. If we eat too little, we develop cramps and neurological symptoms, and can even die.

But hold on, that doesn't mean you can start munching bumper packs of crisps. Most of us consume too much salt. Excess salt intake is linked to high blood pressure, increasing the risk of heart disease or stroke. The NHS recommends that adults should consume 6g of salt a day, but our intake is nearer 8g. Yet working out how much we eat can be tricky because salt is hidden in many foods. A whopping 75 per cent of salt we eat comes from foods like bread, baked beans and biscuits, while salt added during cooking and at the table makes up a small amount of our intake.

And there are other benefits of cutting salt. I often meet patients who cut out fluids during

A  
whopping 75  
per cent of salt we  
eat comes from  
foods like **bread,  
baked beans and  
biscuits**

the day to try to reduce their night-time trips to the loo. That's harmful and can affect kidneys. A recent Japanese study presented to the European Association of Urology congress has found that cutting salt intake can reduce frequency of nocturnal urination. – SA

**VERDICT:** Keeping salt intake down can help blood pressure stay healthy.

## CHOCOLATE

I love chocolate, but I have always seen it as a guilty pleasure. So should I feel bad about eating modest amounts?

Chocolate contains cocoa, and cocoa is a good source of iron, magnesium, manganese, zinc and phosphorous. Cocoa is also rich in antioxidant flavonoids. The downside of your favourite chocolate bar is all the added fat and sugar.

So how well does the good stuff stack up against the bad stuff? Chocolate's main claim to health is its effect on your arteries. In 2012 a systematic review of the effects of cocoa consumption on blood pressure, which looked at 20 studies involving over 800 people, concluded that: "Flavanol-rich chocolate and cocoa products may have a small but statistically significant effect in lowering blood pressure". But the team pointed out that most of the studies they looked at took place over a short period of time (between two and eight weeks) and the size of the effect was not impressive.

A more recent paper, published in the journal *Heart* in 2015, also gave hope to lovers of chocolate. In this study, researchers asked nearly 21,000 men and women from Norfolk to fill in detailed food questionnaires and then followed them for an average of over 11 years. What they found was that those eating the most chocolate (up to 99g a day) had the lowest risk of developing heart disease or stroke.

Their conclusion was that "higher chocolate intake is associated with a lower risk of future cardiovascular events". However, the researchers go on to say there may have been confounding factors at play, such as the chocolate eaters being more active. – MM

**VERDICT:** The odd square of dark, cocoa-rich chocolate isn't going to hurt, but the jury is out as to whether it will do you any good.



## FRUIT

An apple a day keeps the doctor away, or so 'they' say. Along with the rest of the inhabitants of the fruit bowl, apples have a reputation of being able to lower the risk of mortality.

But how true is this? Plenty of studies out there show that people who eat fruit tend to be healthier than fruit-shunners, and have reduced risks of cardiovascular disease and cancer. This could be because fruit contains vitamins and fibre, which are good for health, as well as antioxidants that repair cells.

Yet the debate around the daily amount of fruit to consume continues. A *BMJ* study suggests if you can stretch to seven portions of fruit and vegetables you're doing yourself some real favours. Risk of disease development over the course of the study reduced by 42 per cent for seven or more portions of fruit and veg. The government's current advice sticks at five daily portions. We still have problems reaching that target, let alone increasing it.

But don't get your fruit fix by swigging back juices or smoothies. Many fruit juices contain large amounts of water and sugar. And juices that are 100 per cent fruit still contain almost as much sugar as a sweetened drink. You're better off eating the actual orange than drinking it.

And here's another excuse to slip that apple into your teenager's school bag. Recent studies reveal that a high intake of carotene-rich fruit – such as apples, oranges, bananas and grapes – during adolescence is associated with a lower risk of breast cancer. Just three portions of fruit a day could reduce the risk of breast cancer by an impressive 25 per cent. – SA

**VERDICT:** Start the fruit habit early, but eat it in its natural form rather than squished into juices and smoothies.







## BUTTER

In recent years there has been an ongoing debate about butter, which has led to consumer confusion in the supermarket chilled section. Let's set the record straight.

Butter is a saturated fat. For decades, we have been advised to reduce saturated fat in our diets, centring on the argument that it increases bad cholesterol in the blood, which can clog arteries, causing heart attacks or strokes. Public Health England advises people to cut down on saturated fat, based on a review of 15 clinical trials.

On the other hand, researchers at the University of Cambridge presented a study in 2014, published in *Annals Of Internal Medicine*, reviewing existing published data. The team stated that there was no significant evidence regarding a correlation between saturated fats and a higher risk for heart disease. Hence the 'butter is back' headlines that were splashed all over the internet. But those behind the study warned against over-simplification. They had found that there are different types of saturated fats with varying compositions that all do different things – some good,

some bad. While some dairy products might turn out to cut disease risk, that thought wasn't extended to butter. The team agreed with butter being linked to bad cholesterol.

This is backed up by a recent study by researchers from Harvard, who found that a 5 per cent higher intake of saturated fats, like butter, was associated with a 25 per cent increased risk of heart disease. This supports current guidelines focusing on reducing saturated fat intake and replacing butter with oils high in unsaturated fat.

Nevertheless, according to the study you won't see any benefits of cutting out saturated fat if you continue filling up on refined carbs like white bread. It's only by eating complex carbs like vegetables and wholegrains that you can slash your risk. And with that, hot buttered toast remains for me an occasional treat. – SA

**VERDICT:** *Not all saturated fat is created equal, but more research is needed. Stick to olive and sunflower oil for cooking, and use butter sparingly.*

Some dairy goods might cut disease risk, but that thought does not include **butter**



## PASTEURISED MILK

During my rheumatology attachment, my consultant insisted that every patient was given a daily glass of milk. There are recognised health benefits of the white stuff – it's full of nutrients and helps build strong bones.

Recently, proponents have been claiming that drinking raw milk, rather than pasteurised, offers even more health benefits. But what's the difference? Raw milk comes from grass-fed cows and is full of nutrients, including beneficial bacteria like *Lactobacillus acidophilus*. This 'good' bacteria produces vitamin K2, improves absorption of nutrients and normalises gut function. Raw milk contains high levels of vitamins, enzymes and calcium. But it can also contain bacteria that cause food poisoning and can be particularly harmful to children, people who are unwell and pregnant women.

Pasteurisation is a process where heat is applied to milk to destroy harmful bacteria. Unfortunately, it kills the beneficial ones too. Still, according to a 2015 analysis by Johns Hopkins University, consumers are 100 times more likely to get food-borne illnesses from raw milk than pasteurised. For consumer safety, European and North American legislation mandates the pasteurisation of milk, and that's what we buy from shops.

If you want to give raw milk a try, you'll have to go to specialist outlets, like farm shops and markets. Unpasteurised cheeses, like Parmesan, are more widely available because harmful bacteria occur in such low numbers. – SA

**VERDICT:** *Milk is a great way to get calcium and other nutrients, but pasteurised is safer. 🥛*



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# THE SOUND OF PROGRESS

How Abbey Road, the world's most famous recording studio, is changing its tune for the 21st Century

Words: **Russell Deeks**



T

ucked away on a quiet side street in London's affluent and leafy Maida Vale district lies an elegant but unassuming white building. You could mistake it for the headquarters of a law firm or charity, were it not for

the surrounding wall of the property, every inch of which is plastered in graffiti, mostly about The Beatles. For this is no solicitor's office: this is Abbey Road, and it's probably the most famous recording studio in the world.

Though it's most readily associated with the Fab Four's album of the same name, a list of other famous records – from Cliff Richard's *Move It* to Lady Gaga's *Born This Way*, via Pink Floyd's *Dark Side Of The Moon* and Radiohead's *OK Computer* – that were recorded, mixed or mastered at Abbey Road could fill this entire feature. And that's not even counting the film scores for the likes of *Return Of The Jedi* and the *Lord Of The Rings* trilogy that were birthed here. It remains many A-listers' studio of choice to this day, and for a music lover, the sense of history as you walk its corridors is palpable.

The list of the studio's landmark achievements is equally impressive. When it opened in 1931, it was the first purpose-built recording studio in the world. It's where the first-ever stereo record was made, by legendary sound engineer Alan Blumlein in 1935, and it's also where the first-ever digital recording was made in 1979. It's an institution, in other words. But now the music world has changed. More artists are recording from their bedrooms than ever before, and the face of music is changing all the time. So how does a place like Abbey Road keep up?

My visit begins with a guided tour, which has been arranged for 9am. As Abbey Road's head of audio products Mirek Stiles leads the way into the famous Studio 1, I'm struck by two things. Firstly, how big it is – built to make classical recordings, it's large enough to accommodate both a 100-piece orchestra and a 100-voice choir simultaneously. And secondly, how oddly familiar it all seems. I've clearly spent too many Friday nights watching



## THE VERY BEST OF ABBEY ROAD

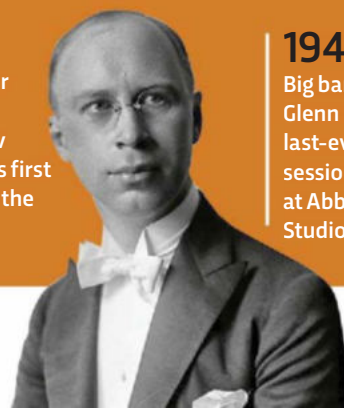
*The studio has seen some famous faces...*

**1931**

Abbey Road Studios opens as the first purpose-built recording facility anywhere in the world.

**1932**

Composer Sergei Prokofiev makes his first record at the studios.



**1944**

Big band leader Glenn Miller's last-ever recording session takes place at Abbey Road Studios.

PHOTOS: GETTY X2, ALAMY X2

# “The studio’s legacy is impossible to ignore: the walls are lined with photographs of musical icons past and present”

music documentaries on BBC Four. I even get to play a few notes on the famous Mrs Mills piano (as used by The Beatles), which sits in the corner.

Studios 2 and 3 aren’t quite as large, but they’re every bit as atmospheric. “This is where *Dark Side Of The Moon* was made,” Mirek tells me casually in the Studio 2 control room. Even in the corridors (where photography is strictly forbidden, due to the high possibility of catching a major star on camera), the studio’s legacy is impossible to ignore: the walls are lined with photographs of musical icons past and present, and every available inch of space is crammed with vintage hardware. “It’s not a museum, it’s just a storage issue!” laughs Mirek. Still, all those clunky dials and meters are enough to set any gear-head’s heart racing...

## INNOVATION, INNOVATION, INNOVATION

After the tour, it’s time to find out how Abbey Road is maintaining its position through a process of constant innovation. That innovation takes three main forms: expanding the studio’s own technological ‘offer’; making its prowess available to an ever-widening demographic via dispersion line products; and partnering with music tech start-ups.

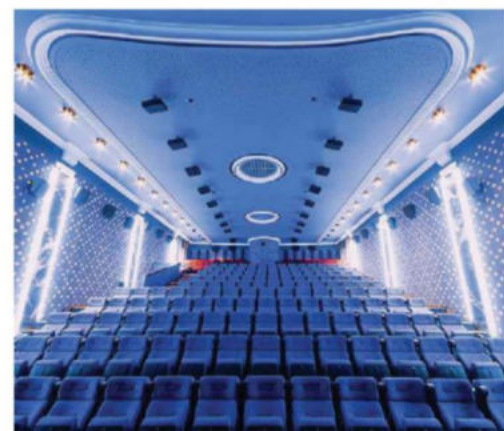
In terms of Abbey Road’s own facilities, the studio has recently undergone the biggest expansion in its history, adding two new recording suites – the Gatehouse and the Front Room. Modern producers, working largely in the digital sphere, often don’t need the enormous live rooms that Studios 1, 2 and 3 have to offer, so the new spaces offer a more compact, affordable option. As Stiles puts it: “It’s just more realistic in terms of the recording budgets up-and-coming artists are given these ●

## WHAT IS DOLBY ATMOS?

*Dolby’s latest surround sound wizardry explained*

Atmos is Dolby’s newest way of generating realistic surround sound. It works by employing multiple speakers – and not just the 5.1 or 7.1 channels you might be used to in a home cinema setup. A fully-fledged Dolby Atmos cinema can utilise up to 64 speakers, although you can create a convincing Dolby Atmos system with far fewer.

The key difference between Atmos and previous systems is that Atmos employs not just left/right/centre and front/rear speakers, but top (ceiling) and bottom (floor) speakers as well. For producers



of movie soundtracks, this means separate channels have to be created for each of these speakers – hence the arrival of the Mix Stage post-production suite at Abbey Road.

The likes of Yamaha, Samsung, Kef, Pioneer, LG and Onkyo all sell Atmos-compatible products, from soundbars to AV receivers, and interestingly, the technology isn’t limited to AV applications – Ministry Of Sound in London recently became the first nightclub in the world to have a Dolby Atmos sound system installed.

**1952**

*Cowpuncher’s Cantata* is the first single recorded at Abbey Road to feature on the brand new Official UK Singles Chart.

**1953**

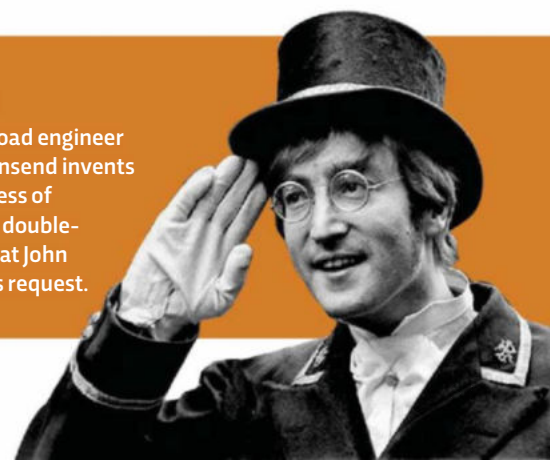
Queen Elizabeth II’s coronation is recorded at Abbey Road via a private landline.

**1955**

The first stereo record is released, two decades after Alan Blumlein was granted a patent for the technology.

**1966**

Abbey Road engineer Ken Townsend invents the process of artificial double-tracking at John Lennon’s request.





## MUSIC

► days. We've got brand new Neve and SSL desks in there, and the latest version of Pro Tools, but people have access to our vast archive of vintage gear as well, so it's a mix of the old and the new."

Another new addition is the Mix Stage, a purpose-built Dolby Atmos post-production suite complete with a huge 4K screen, for mixing film scores. "It makes us the only studio in the UK that's capable of not only scoring a film, but also dubbing the soundtrack," says Stiles. "There are lots of places in the States you can do that, but nowhere else in the UK. So we're really excited."

### REACHING OUT

Modern technology has enabled many more artists to record and produce their own music, rather than relying on a record company to fund months of expensive studio time. To appeal to this demographic, Abbey Road has spent the past five years or so working with respected hardware and software companies to develop realistic emulations of its previously exclusive technologies, so any bedroom music producers can use the studio's exclusive, high-end tech.

Among the most popular products in Abbey Road's range are the series of virtual drum instruments. Each of these – Abbey Road 50s Drummer, 60s Drummer, 70s Drummer, 80s Drummer, Vintage Drummer and Modern Drummer – faithfully recreate the kind of drum sound you'd have got if you recorded at the studios during the period in question. To do this, a drum kit from the period is played at Abbey Road, with every possible 'articulation' (light, medium and heavy snare hits, cymbal crashes, etc) recorded using an entirely contemporaneous signal chain – so a 1950s drum kit will be recorded using a 1950s microphone, running via a 1950s mic preamp into a 1950s mixing desk, put through a 1950s compressor/limiter and recorded on a 1950s tape machine. With over 40,000 individually recorded sounds in each package, the attention to detail here is staggering. A similar process was used to create CFX Concert Grand, a software recreation of the legendary Yamaha concert grand piano found in Studio 1. A snip at £175, compared to nearly £120,000 for the real thing!



Two of the most recent additions to the line-up are the Abbey Road Vinyl Plug-in, which faithfully models the studios' vinyl cutting and playback gear, and will add 'vinyl warmth' to digital productions, and the REDD Microphone – the first microphone in the world to have a preamp built into the mic itself. Both have been well received, says Stiles. "The vinyl plug-in has been particularly interesting, because we've found people are using it to cut individual tracks – drums, vocals or guitars – to vinyl, prior to the final mixdown. That wasn't really feasible before."

For the past year Abbey Road has also been running Red, a mentoring programme for start-ups. "Whether it's help with engineering or advice on marketing, there's almost certainly someone within EMI/Universal who has the necessary expertise," says Red programme manager Jon Eades. "My job is to stay in contact, find out what the companies need, and then find someone at Abbey Road who can help."

Start-ups involved so far have included headphones manufacturer Ossic; online mastering service Cloudbounce; *Uberchord*, a guitar tuition app that can analyse chords you play and tell you

### 1967

The world's first live global satellite broadcast features The Beatles playing *All You Need Is Love* at Abbey Road.

### 1969

The Beatles' iconic *Abbey Road* album is released.



### 1972

Quadrophonic recording equipment is installed, though the format is to prove a commercial failure.

### 1973

Pink Floyd record *Dark Side Of The Moon* in Studio 2, using the new TG12345 MK IV 16-track mixing desk. The desk recently sold at auction for £1.45m.





## “Visually, VR is amazing – but unless you’ve got the sound to back that up, you’re only getting half a story”

and it all seems to be going back to two quite old technologies: binaural and ambisonics,” Stiles says.

Binaural recording uses filters to mimic the way your ears *actually* hear, taking into account your nose and ear shape, and how sound gets distorted between the source and your brain. It was invented in 1935 by Alan Blumlein, but it was never really utilised. Ambisonics was invented in 1975 by Oxford professor Michael Gerzon. It recorded sound in many different directions by using lots of capsules, much as a 360° camera uses multiple lenses today.

“So today, we’ve got this problem of how to create convincing 3D sound in headphones,” continues Stiles, “and it’s coming down to a technology from 1975 and another from 1935! So now I’m basically gatecrashing people’s recording sessions with the ambisonic mics, recording things and then playing about with the software in post-production. Getting my feet wet, trying stuff out and making sure that, if this does kick off in a big way, Abbey Road knows what it’s doing with it.”

Stiles’ enjoyment of his job is written all over his face. Which is probably why he’s been at Abbey Road for over 20 years – although, as he says, such longevity is fairly common at the studios. “You tend to start working here and you don’t really want to leave,” he smiles. “Just the breadth of different work that comes through keeps it interesting. It’s an amazing place to be!”

**Russell Deeks** is a freelance writer and editor, specialising in music and technology.

where you’re going wrong; *Scored*, an app that helps aspiring film-makers soundtrack their own movies; Qrates, an on-demand vinyl pressing service that’s proved extremely popular with small record labels; and Audiohunt, which began life as a peer-to-peer marketplace for high-end audio equipment but has since transformed itself into a kind of Uber for music processing, whereby a producer says, “I want this track passed through an XYZ limiter,” and the first XYZ owner to respond gets the gig.

“We’re really pleased with how it’s gone so far,” says Eades. “Bear in mind that we’re not just helping them out here – we’re also potential customers or partners, so it’s in our interests to make it work!”

### VIRTUAL INSANITY

Stiles is also involved in Red, and his work with Ossic to develop convincing 3D headphones for VR is an example of how Abbey Road is embracing innovation and drawing on its long legacy.

“Everyone’s excited about virtual reality, and visually, VR is amazing – but unless you’ve got the sound to back that up, you’re only getting half the story. So 3D audio is attracting interest right now,

Engineers used high-tech microphones to record Abbey Road’s grand piano in Studio 1, this raw material then allowed them to create CFX Concert Grand software

PHOTOS: ABBEY ROAD STUDIOS, GETTY

**1979**

First digital recording, of André Previn and the London Symphony Orchestra.

**1981**

*Raiders Of The Lost Ark* is the first film score to be recorded at Abbey Road.

**1994**

English rock band Radiohead record their second album *The Bends* in Studio 3.

**2005**

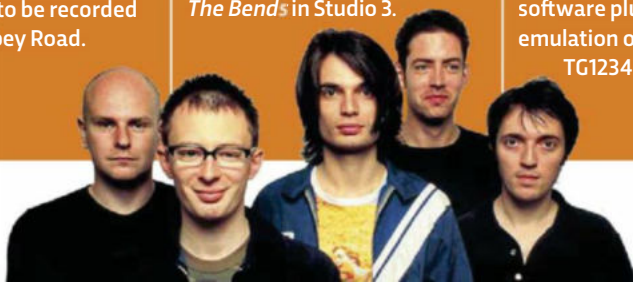
Abbey Road launches its first software plug-in, an emulation of the TG12345 limiter.

**2009**

Abbey Road’s online mixing and mastering service is launched.

**2010**

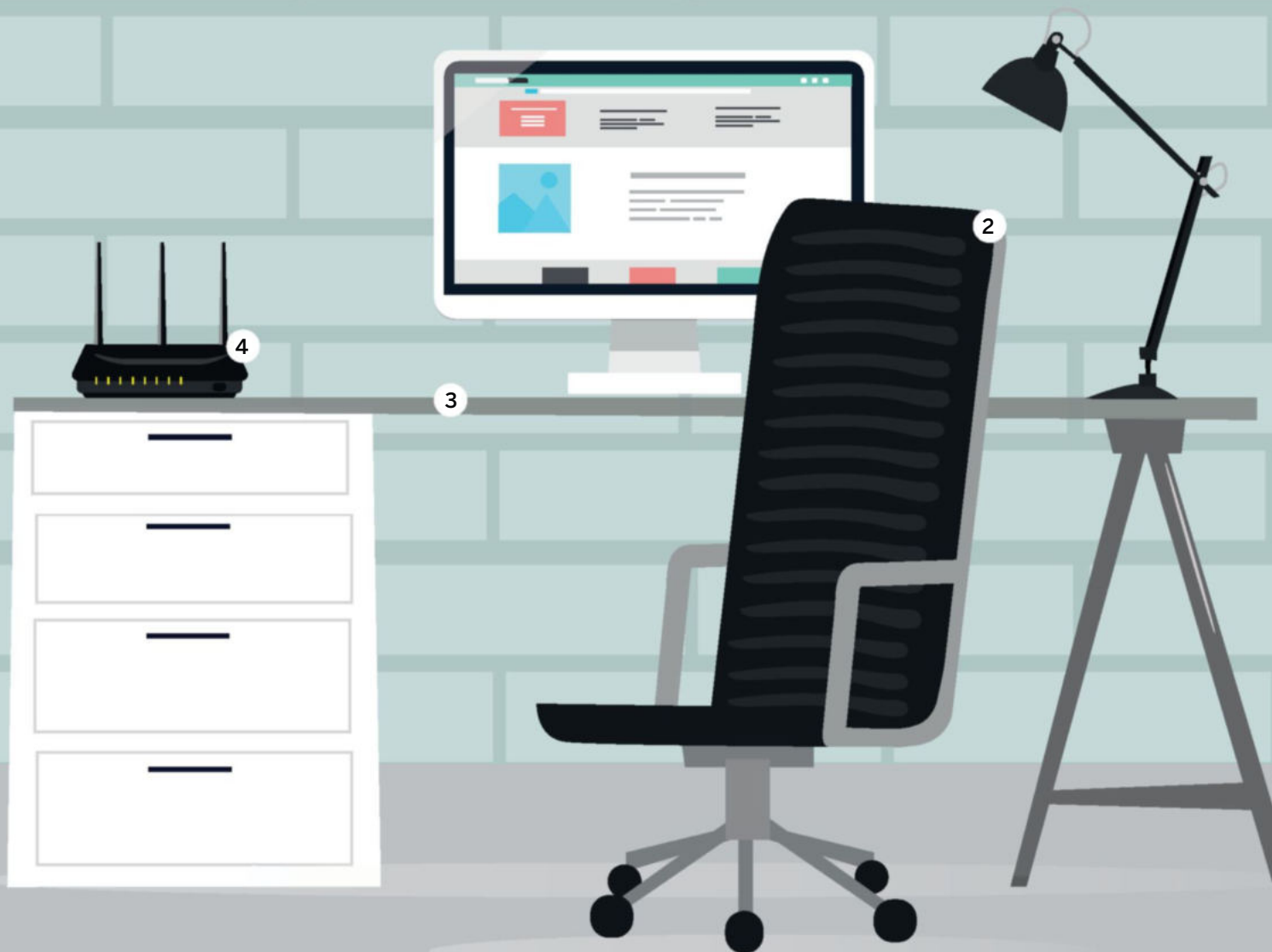
Colin Firth’s speech for the film *The King’s Speech* is re-recorded at Abbey Road using the actual microphone used by King George VI.





# STUDY IN STYLE

If you're looking to aid your concentration and streamline your workflow, the first thing to look at is your environment. Sort out your office space, with these top-of-the-range home selections





1



kukoon.com

## Graphite Grey Trellis Rug Havana

1

This carved trellis design in grey and cream is inspired by the East. The trellis rug is the new trend among interior designers as it gives a real vintage feel with a modern twist, perfect for adding colour and warmth to your room setting.

From £27.95 [kukoon.com](http://kukoon.com)

2

## Abbey High Back Leather Office Chairs

It's important to love your workspace, so add some style to your study with this Italian-inspired high back executive chrome office chair. This chair is available in four colours and with free next-day delivery. **£134 (ex VAT)** [OfficeFurnitureOnline.co.uk](http://OfficeFurnitureOnline.co.uk)



officefurnitureonline



officefurnitureonline

## Arctic Ergo Glass Computer Desk

3

The Arctic Ergo Glass Computer Desk is a best seller from the UK's largest online retailer of office furniture. It's the perfect surface to make your ideas happen. Order before 3pm for free next-day delivery. **£189 (ex VAT)**

[OfficeFurnitureOnline.co.uk](http://OfficeFurnitureOnline.co.uk)

4

## The Synology RT1900ac

This high-speed wireless router provides swift and reliable Wi-Fi connectivity. It comes with a dual core CPU, USB 3.0 port, SD Card reader and an intuitive user interface accessible via web browser or mobile app. **£120.75 (ex VAT)** [www.synology.com](http://www.synology.com)



Synology





# LOST AND FOUND

In 2012, over the course of 72 hours, **Vanessa Potter** rapidly lost her sight. At the same time, **Bella Bathurst** was recovering from a deafness that had robbed her of music and conversation. Both women regained their senses – a journey that led them to re-evaluate how our brains make sense of the world around us. They were both inspired to write books about their experiences, so we sent **James Lloyd** to introduce them to each other and to hear their stories

PORTRAITS BY MAX ALEXANDER

**Vanessa, when did your sight begin to disappear?**

**VP:** Two weeks before it all happened, I'd had a horrendous flu-like virus, but I recovered enough to go on a day out with family friends. On the way home, though, my eyeballs began to hurt. When I woke up the next day, on 1 October 2012, I opened my eyes but couldn't come to consciousness. I had a static kind of disturbance. I could still see, but my vision had gone dark – it was knocked out.

**What happened next?**

**VP:** I spent a day in hospital but they couldn't find anything and sent me home. When I woke up the next morning, I'd lost about 70 per cent of my vision. I had a misty brown fog over everything,

**“I think I worked harder, partied harder, and just did everything that much more. That was my not-very-evolved coping strategy!”**

and over the next two days, my sight literally slid away. I knew it had gone when I was pushed out into the sunlight in a wheelchair, and I didn't get any light shift. There was nothing. And by that time, I'd also developed paralysis in my hands and legs, so I was losing my sense of touch, too.

**Bella, was your hearing loss equally dramatic?**

**BB:** Mine was more gradual. I had two head injuries in my twenties – first a skiing accident and then I turned my car over on black ice. I started going deaf fairly quickly after the second accident, over a period of about six months, and I completely ignored it. When I eventually got tested at St Mary's [Hospital], they said I was down about 50 per cent in both ears. It looked like the head injuries were the cause, so they gave me some hearing aids and I just got on with it. Over the next 12 years, my hearing went down to about 20 to 30 per cent.

**How did you cope?**

**BB:** I had a defiant sort of response: I took it as a challenge to carry on. I was working as a journalist and writer, and I'd just started my first book so I was doing a lot of interviews. I think I worked harder, partied harder, and just did everything that much more. That was my not-very-evolved coping strategy! ●



● **VP:** I had full sensory loss visually, but my physical body still had some messages coming through, so I got a lot of very strange data. My body would tell me I was underwater, or that my feet were encased in thick ice. I coped by retreating inwards. I'd had some experience of meditation and hypnobirthing, so I created a visual picture of a beach where I could go and practise seeing again. It was a safe place, and I was probably there up to 80 per cent of the day. Over the weeks, I got to control the light and movement. I was firing up that visual part of my brain, even though I didn't realise it at the time.

**When did your recovery begin?**

**VP:** I was in hospital for 16 days. My vision hit the bottom, and then it started to splutter back into life. I saw a flat, grey, mutating world. I couldn't see faces or people, but I would know there was a light source, and I started to see edges and lines. I was probably legally blind for a month. Today, I still have 'visual snow' – it's like looking through a gauze or a mist – and I have profound colour loss.

**BB:** At the time I went deaf, the clues seemed to be pointing towards sensorineural hearing loss. This type of loss is permanent, caused by damage to the hair cells in the inner ear or to the auditory nerve.

But when they retested me 12 years later in 2009, it became clear that I actually had conductive hearing loss, the other main type of loss. I was diagnosed with a condition called otosclerosis, in which the stapes bone in the middle ear stops vibrating and conducting sound properly. So it had nothing to do with those head injuries – they were a total red herring.

**Was the condition treatable?**

**BB:** Yes, I had an operation which involved taking out the stapes and replacing it with a prosthetic implant. There was a gap of a year between the two operations, one on each ear. After the first operation, on my left ear, my hearing suffered a traumatic crash, similar to Vanessa's vision. I had distorted sound: it was like listening to Brian Eno with one ear underwater. But that ear slowly recovered, over a period of about six weeks. The second operation went fine, and now my hearing is pretty great.

**Vanessa, did you get an official diagnosis?**

**VP:** They don't really know. I'm under the umbrella of 'neuromyelitis optica' (NMO), which is a rare autoimmune neurological disease. But I don't really tick all the boxes, so I'm even more unusual. It seems that the virus stimulated my immune

Vanessa (right) describes her sight loss to Bella



# “When I couldn’t see, someone’s hand was able to transmit so much emotion. Touch has no judgment, it’s empathy and compassion”

system, which overreacted and just carried on attacking my optic nerves and spinal column. With autoimmunity, the most profound thing I learnt is that you heal yourself. I had vitamin B injections and a treatment called plasmapheresis, but in the end it’s all down to your own biochemistry. How you process your thoughts and feelings has such an impact on that.

## Did you find that your other senses became stronger to compensate for your loss?

**VP:** Having two of my major senses knocked out let some of the more subtle, whispering senses take over. I knew that my daughter had a red school dress, and although I couldn’t see it, I could *feel* the colour. That was my lifelong emotional attachment to the colour red coming through, a sense of warmth. I also had a kind of blindsight. I was shuffling across the floor with my walking stick, and had this strong sense that I needed to stop and pick something up. I bent down and found this tiny, tiny piece of orange pith. I couldn’t explain it. Our bodies absorb all this data through channels that we don’t even understand; there’s all this higher processing going on.

**BB:** I’d get phantom pains and smells. I’d be wandering around my flat and there’d suddenly be a strong smell of patchouli or bonfires. It was like my other senses were going “testing! testing!”. And my sight did what deaf people’s sight often does. Generally, people conceal their sense of sight. We don’t tend to stare: it’s very intimate. It’s as if our vision is on a dimmer switch. But with deaf people, all the lights are on. They look in a completely different way, because sight has to do the job of both senses.

**VP:** We see what we need to see. If we took in our whole visual picture, it’d be complete overload because there’d be too much going on. But with reduced sight I could turn this around and ask my husband to describe what was in front of me. This would stimulate my brain to ‘see’ it, not as a big pop-up picture, but in a very subtle way. I was teaching my brain to revisualise.

## What was it like to have your senses back?

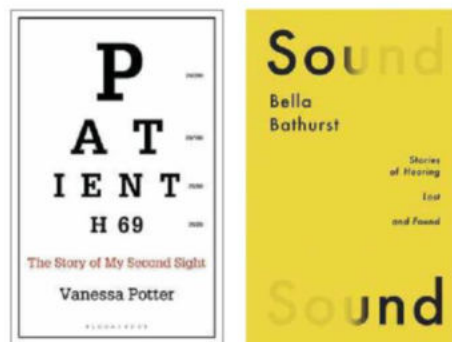
**VP:** I think if you take away something and then give it back, you’re immensely grateful. You look at life a little differently – you see the things that you’re capable of.

**BB:** Being stupendously nosy by nature, I loved getting back the capacity to eavesdrop. That thing when you catch a fragment of someone’s conversation as you walk down the street, without any context. “And they gave his head back to me in a jar”. I’m still trying to work that one out. And when I get woken by urban noises – car alarms, angle grinders, sirens – it makes me happy every time. There’ll be something like that every day, like the washing machine spin cycle, where I just think, “oh my god, that’s lovely.”

## What other positives have you taken from your experiences?

**VP:** It’s taught me how resourceful I can be, and I also got to experience other people and their compassion. I had visitors every single day for four months. I was the dog, and everyone came to walk me. When I couldn’t see, someone’s hand was able to transmit so much emotion. Touch has no judgment, it’s just pure empathy and compassion.

**BB:** I’m profoundly glad I went through the experience. It turned into a fairly fundamental reboot, and it showed me just how much of communication has nothing to do with speech. It also taught me what sound can do. After my second eardrum had more or less healed, my friend got me tickets for the Berlin Philharmonic. They were playing Schubert and Haydn, and when the first notes struck up it was a full-body experience. The vibrations from the orchestra did something to my insides that I can’t really quantify. It was like somebody going into a power plant and slamming their hand down on all the fuses. I think it was almost all worth it just for that experience. Almost. 🐶



*Patient H69* by **Vanessa Potter** (£16.99, Bloomsbury Sigma) and *Sound* by **Bella Bathurst** (£14.99, Profile Books) are both out now.



# CONNECTING TO THE **WOOD-WIDE WEB**



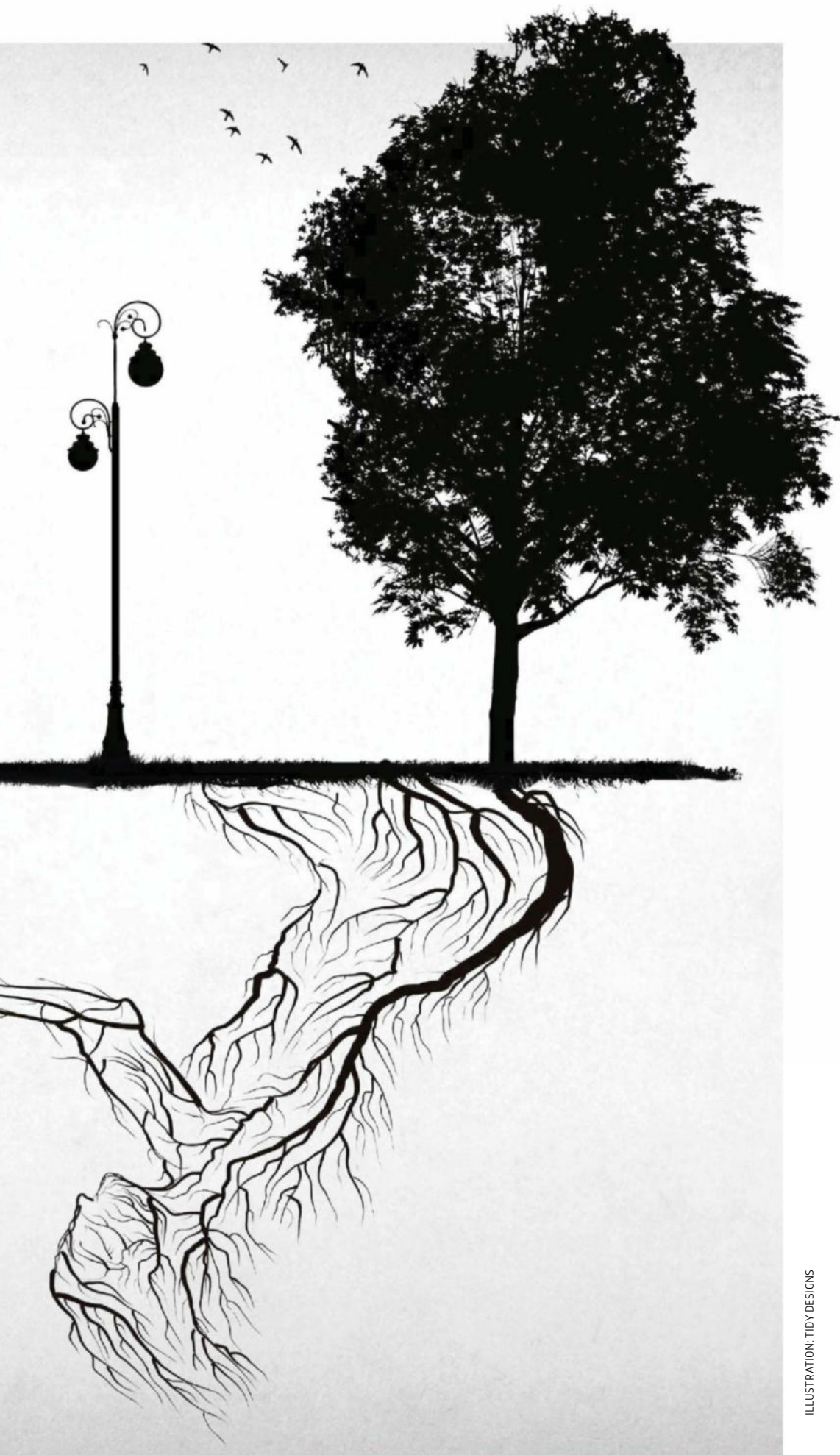


ILLUSTRATION: TIDY DESIGNS

Deep in the forest, all is not as it seems. There's growing evidence that trees can talk to each other via a vast, underground network of fungi...

WORDS: JOSH GABBATISS

**W**hen Prof Suzanne Simard realised the trees were talking to each other, it didn't

come as a huge surprise. She started her career as a forester, working with trees planted in uniform rows, but the nature she knew didn't come in rows. It was incredibly messy, complex and connected.

"If you walk in a wild forest, you can see that the plants are intertwined, they provide habitat for one another," she explains. Nature, as Simard sees it, is a network: a mass of interacting components that rely on each other to function.

This was in the 1990s, and exciting new discoveries were emerging about underground associations between fungi and plant roots, termed mycorrhiza (literally 'fungus-root'). "At the time, lots of people in forestry were looking at how trees compete for light," explains Simard, who is now a forest ecologist at the University of British Columbia. "But I got more and more interested in what was going on below ground, because I figured out that was where the action was."

She was right. Beneath our feet, plants are engaged in a constant dialogue. Stories of friendship, greed and betrayal are unfolding across a subterranean network, a microscopic version of the connections Simard could see in her beloved forests above ground. This network has come to be known as 'the wood-wide web'. Let's plug ourselves in. ●



● Mycorrhiza are everywhere. Every step you take through a forest can cover hundreds of kilometres of densely packed fungal threads. These are the fibre optic cables of the wood-wide web. The fungus forms mycorrhiza with plant roots, and through those connections pass substances that both organisms need to grow.

This relationship has been understood for decades as a straight-up exchange between plants and fungi: plants provide carbon-rich sugars made by photosynthesis, and in return they get nutrients, such as phosphorus and nitrogen, that the fungi scavenge from the soil.

### TREE LANGUAGE

Yet there is another level of interaction; an exchange not only back and forth between the fungus and the plant, but also between neighbouring plants, using fungi as a thoroughfare. As the fungal threads spread, they can link up to multiple plants, creating webs known as 'common mycorrhizal networks'. Through these networks, plants can exchange sugars, nutrients, water and more.

"I call it 'the language of the trees'," says Simard, and apparently the trees have a lot to say for themselves. By encouraging plants that are connected by common mycorrhizal networks to suck up isotopes (isotopes are atoms of an element with different numbers of neutrons) of a resource like carbon, it's possible to trace the resource's progress from one plant to another. From this research, a picture emerges of individuals sharing

with those in need, of 'mother' trees sending carbon to seedlings, and of dying trees donating nutrients to their neighbours. Some trees even show favouritism, doling out more resources to closely related plants. Donations of nutrients and water take place across a 'source-sink' gradient, whereby a plant that is rich in a particular resource will give its excess to those in need.

It appears that by staying connected, plants can provide mutual support and help shape the ecosystems they inhabit. With all their inhabitants linked up, forests look less like collections of individuals, and more like giant superorganisms.

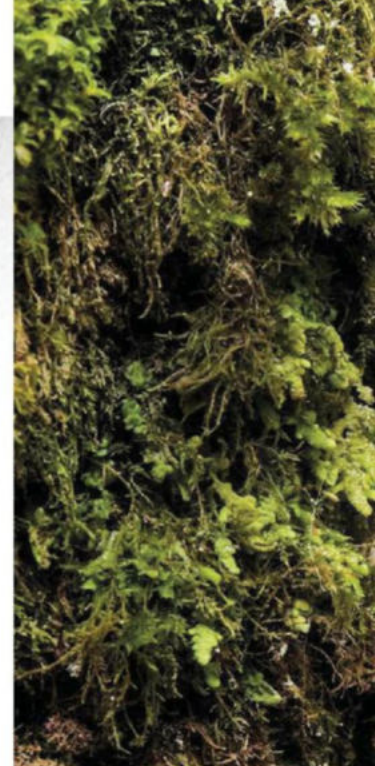
The wood-wide web is not confined to woods, however. Mycorrhiza occur anywhere you find vegetation, from tropical rainforests to Arctic tundra, and they benefit the growth of the vast majority of land plants. The networks they form are complex, often encompassing not just multiple plants but multiple species, and depending on the type of fungi involved, different materials can be exchanged. In the past few years, researchers have demonstrated that plants connected to the wood-wide web can exchange more than just nutrients.

When broad bean plants come under attack by aphids, they release chemicals that not only repel their attackers, but also attract wasps that prey on the aphids. It's an ingenious, two-pronged defence strategy. Prof David Johnson, a microbial ecologist at the University of Manchester, wanted to find out if mycorrhizal networks could be used to send out advance warnings, letting plants know that an attack is on its way. To do this, he introduced aphids to plants and watched how their neighbours reacted. "What we found was that plants have the same response when their neighbour is attacked," he says, "but only when their root systems are connected by these common mycorrhizal fungal networks."

This fungal communication is slow, more dial-up than broadband, but nevertheless it seems to be playing a role in relaying messages between plants about everything from hungry caterpillars to harmful pathogens.

### NICE OR NASTY?

So far, so friendly. The idea of plants giving a helping hand, or branch, to their neighbour is nice,



BELOW:  
A network of fungi  
covering the root of  
a eucalyptus tree







ABOVE:  
The 'above ground'  
part of a mushroom or  
toadstool is just a tiny  
bit of it

but evolutionary biologist Prof Toby Kiers of Vrije Universiteit Amsterdam thinks it's unrealistic. "We see harmony because we want to see harmony," she explains. "It fits with our world view of nature as the ultimate nurturer. But look under the surface, and it is anything but harmonious." After all, in any environment with limited resources, a neighbour is really just another name for a rival.

Work by Kiers and her colleagues suggests that when different species of plant are connected to the same fungal network, they will invest less in sustaining the fungi. To her, this makes perfect

*"A picture emerges of individuals sharing with those in need, of 'mother' trees sending carbon to seedlings, and of dying trees donating nutrients to neighbours. Some trees even show favouritism"*

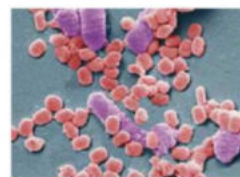
sense. If fungal networks are benefitting a plant's rivals, why invest in them?

Like its online counterpart, the wood-wide web has a dark side. For every birch donating carbon to its fir neighbours, there's an orchid stealing carbon from nearby trees. For every plant that informs others of a disease outbreak, another sends out toxins to kill its rivals. Competition, at least as much as cooperation, defines the wood-wide web.

Even seemingly friendly exchanges might not be all they seem, however. Dr Kathryn ●

## NATURE'S NETWORKS

*It's not just plants that team up with their neighbours for the greater good*



### BACTERIA

Though they are simple organisms, bacteria can perform complex collective actions. All they need is 'quorum sensing', a system by

which they release signalling molecules, assess the concentration of these molecules, and respond when a threshold value is reached. This kind of coordination allows bacteria to colonise hosts and defend against competitors.



### LOCUSTS

The experience of being in a crowd encourages locusts to make the switch from solitary insects into members of vast swarms.

Cramped conditions initiate an influx of serotonin into their bodies, causing physical changes as well as making them more sociable.



### EUSOCIAL INSECTS

No individual ant or termite has the sense of what their finished nest will look like. Instead, the workers use local information in

the form of pheromones to direct their behaviour, allowing incredible constructions to emerge from simple actions. It's a kind of insect algorithm.



### FISH

For fish, schooling is a means by which to avoid predation through safety in numbers. Research into three-spined

sticklebacks has revealed two groups of genes in fish associated with both the inclination to join others in a group and the ability to remain in formation once there.



### STARLINGS

Famous for their enormous flocks, or 'murmurations', starlings also gain protection from predators by gathering

in numbers. Individuals are able to stay totally coordinated with the whole group by simply keeping an eye on their seven closest neighbours and moving accordingly.



# *"Are these societies socialist utopias, with resources equally distributed among all the stakeholders, or are mycorrhizal networks controlled by capitalist plants?"*

● Morris at Xavier University in Ohio has spent years eavesdropping on both the 'nasty and nice' conversations that plants have via mycorrhizal networks.

"It's tempting to think of the plants as helping other plants," explains Morris, highlighting the particularly cuddly example of older trees 'feeding' seedlings with carbon. But rather than being fed, she says, you could just as easily view this as younger trees parasitising the network.

## **FUNGAL CONTROL**

So what about the fungi? Although the relationship between plants and fungi appears to be mutual, here too we find individuals looking out for number one. "At the basis of all cooperative relationships is conflict," explains Kiers. "We all

want to maximise the payoffs from the relationship. Plants and fungi are no different." In this case, the plants and the fungi want to extract the resources they need from their partners while giving as little in return as possible.

While experiments have often treated fungi as mere pathways in mycorrhizal networks, they probably take far more of an active role. "There's good reason to think that they should be in some sort of control," says Johnson. The very formation of the wood-wide web – fungi linking up with multiple plant hosts – may only occur because the fungi benefit from having a diverse set of partners from which to obtain carbon.

Fungi are generally at a disadvantage, because while plants could still extract nutrients from the soil without them, many mycorrhizal fungi are entirely dependent on the plants for survival. To level the playing field, fungi in these networks could be restricting their plant host's access to resources, creating what Kiers calls "an addiction of sorts". "If I restrict your direct access to food, you become more dependent on me to provide that food," she explains.

At present, most investigations have been limited to establishing the movement of signals or resources from plant A to plant B. "A mycorrhizal network is incredibly complex, and the fact that we can even detect a signal going from one plant to another is amazing," says Simard, who thinks there are many different mechanisms driving

## SMARTY PLANTS

*Five more remarkable adaptations that help plants to survive and thrive*



### **THE LISTENER**

Classical music certainly won't make your plants grow bigger, but that doesn't mean they are completely indifferent to sounds in their environment. Playing recordings of chomping caterpillars to *Arabidopsis* plants is enough to make them flood their leaves with chemicals designed to ward off attackers.



### **THE CARNIVORE**

Venus flytraps rely on touch to know when they should close on a victim, and they have even learned to count in order to avoid false positives. To ensure that they're capturing a living, wriggling creature, traps only shut after two taps, and will only begin digesting prey after three more distinct touches.



### **THE STRANGLER**

A parasitic plant known as the dodder vine locates its prey by scent. When odours from a tomato plant are wafted towards the vine, these chemical cues prompt the plant to send a tendril snaking towards the source. This vampiric tendril will wrap around its victim before extracting the goodness from within.



### **THE BAT-LOVER**

A species of Bornean pitcher plant gets its nutrients from bat poo, and the best way to secure a steady supply of this niche foodstuff is by encouraging bats to roost inside it. To do this, the plant has evolved a reflective hood that bounces bats' calls back at them, enticing them to visit and settle down.



### **THE LIGHT PIPER**

Plants have light receptors in their roots, but until recently the reason for this was unclear. Last year, research revealed that the stem of the thale cress plant behaves like a fibre optic cable, funnelling sunlight down into the root system, where it triggers the production of proteins that promote healthy growth.



1. Some mycorrhizal species (solid lines) cover the roots of plants and form networks

2. Other species (dotted lines) actually penetrate the cells of the plant roots, but also form networks

3. Orchids are intriguing as they can only germinate with the help of mycorrhizal fungi

communication across these networks. Morris, for example, has been exploring the idea that the transfer of signals is a passive process, with chemicals hitching a ride on water that was moving around anyway. For the most part, however, the mechanisms of transfer still remain unknown to us.

“There are a million pathways that can go in all kinds of directions, and so to think that it’s only one mechanism, or to think that the fungi themselves are not involved, is too simplistic,” explains Simard.

### LOW SOCIETY

Language, superorganisms, wood-wide web – discussion of mycorrhizal networks is certainly not short of metaphors, but none of them quite captures these networks’ complexity, with their subtle blend of cooperation and conflict.

Perhaps the most effective description is the one preferred by Simard: “The work I’m doing is a huge metaphor for how we relate with each other, and our own social systems,” she says. “We have

journalists, scientists, teachers, doctors, and all together we have a society. And if you take out all the teachers that system doesn’t work any more.” For an ecosystem to remain functional, it requires every one of its components to be in place.

So are these societies socialist utopias, with resources equally distributed among all the stakeholders, or are mycorrhizal networks controlled by capitalist plants seeking to exploit their connections for profit? Well, maybe they are a little bit of both. Just like human society, this plant society is characterised by variety, with its capacity to help and to hinder, to cooperate and to exploit. Just as Simard suspected, nature is built on connections, and so are we. 🌲

**Josh Gabbatiss** is a freelance science writer, specialising in biology and zoology. He is based in London and tweets from @Josh\_Gabbatiss





: Jeff Forshaw and Brian Cox :  
**GUIDE TO THE COSMOS**



Part III of IV

# THE RULES OF THE GAME

The beautiful symmetry of particle physics  
underlies everything

## About this series

In this exclusive four-part series, physicists Jeff Forshaw and Brian Cox introduce us to the biggest ideas in modern physics and cosmology. What is the nature of time? What is everything made from? What happened before the Big Bang, and how will the Universe end? We'll delve into the deepest questions concerning the very essence of space, time, matter, and reality itself...



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with Brian Cox at

[bbc.in/monkey\\_cage](http://bbc.in/monkey_cage)



Like them or not, rules govern our lives. Some we make, and some we break. But zoom out, and there's one set of rules that overrides them all. These are the rules of particle physics, and if we get to grips with them, we can understand what everything in the Universe is made from, and why everything in the Universe behaves as it does.

The Universe is built from elementary particles. This simple

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## “As far as we can tell, quarks and electrons are not made of anything”

● idea has survived intact since the time of the Ancient Greeks. In the preceding article in this series, we talked about the counterintuitive ways in which these particles behave. The basic rules are not complicated though: each particle can hop around, and in doing so can emit or absorb other particles. For example, an electron can hop from one place to another, emitting or absorbing particles of light (photons) as it goes. Once we know the rules governing how electrons move around, we can begin to understand the behaviour of atoms and molecules, which is the basis for modern chemistry.

In the diagram to the right, we list all of the elementary particles that are known to exist today. Together they make what's called the Standard

Model of particle physics. We can think of these particles as being in a constant dance, hopping and branching as they go. Knowing the rules of the game is tantamount to knowing precisely how the particles are allowed to hop and branch. In other words, we must identify the particles that make up everything in the Universe, and determine the rules governing how they behave.

This is pretty profound stuff, but we shouldn't get too carried away, because knowing the rules of the game isn't everything. There's a nice analogy between particle physics and chess that illustrates this point. Suppose you do not know the rules of chess – well, you could figure them out by watching people play. It wouldn't take you too long to identify the different pieces and, with careful observation, you could also figure out the legal moves (though *en passant* might take a while to discover). Particle physics is just like this – we are trying to learn the rules of the game as best we can by observing nature. Of course, knowing the rules of the game isn't the same as playing like a Grandmaster. Exploring the remarkable and highly complex consequences of the rules of nature is a job tailor-made for chemistry and biology. That said, particle physicists have discovered that the rules themselves are beautiful.

### NATURE'S MIRROR

You might be forgiven for thinking that the rules governing how the elementary particles behave are very complicated. After all, these rules are supposed to underpin the entire range of natural phenomena, from the evolution of stars to the structure and colour of a flower. Perhaps it is necessary to encode all of these laws in huge books that fill entire libraries: giant catalogues of intricate detail. Or perhaps everything can be encoded on the back of an envelope. Because, as it turns out, the fundamental laws of nature are incredibly simple.

Take a look at 'The key idea' (right). It illustrates how symmetry can play a profound role in shaping our understanding of the world. In the case of a snowflake, symmetry allows us to draw the entire ●



## STANDARD MODEL OF ELEMENTARY PARTICLES

$u$ up	$c$ charm	$t$ top	$g$ gluon	$H$ Higgs
$d$ down	$s$ strange	$b$ bottom	$\gamma$ photon	
$e$ electron	$\mu$ muon	$\tau$ tau	$Z$ Z boson	
$\nu_e$ electron neutrino	$\nu_\mu$ muon neutrino	$\nu_\tau$ tau neutrino	$W$ W boson	

QUARKS LEPTONS GAUGE BOSONS SCALAR BOSONS

These are the elementary particles, which together make up the Standard Model of particle physics. All of the atoms in the Universe are built using only the electrons and the 'up' and 'down' quarks. These interact with each other and stick together with the help of gluons and photons. Gluons transmit what is known as the 'strong force' that binds together quarks to make protons and neutrons, the building blocks of atomic nuclei. Photons transmit the electromagnetic force that acts between electrically charged particles, like electrons.

The other particles in the table are also important, but for less evident reasons. For example, around 60 billion electron neutrinos stream through every square centimetre of your body every second. These neutrinos are made inside the Sun, as a by-product of the process that fuses hydrogen into helium. The 'weak force' is responsible for this process of nuclear fusion and is transmitted by the W and Z particles.

The particles in the second and third columns of the Standard Model are like heavier copies of those in the first column. The existence of these heavier particles was crucial in governing the behaviour of the Universe shortly after the Big Bang, of which we will learn more in the final article in this series.

## The key idea

### SYMMETRY SHAPES OUR UNIVERSE



Symmetry is helpful because it allows us to complete the picture of a snowflake even though we only have half a picture. The same idea is relevant when it comes to writing down the mathematical equations that govern how the elementary particles of nature behave.

$$\bar{\psi} i \not{\partial} \psi \longrightarrow \bar{\psi} (i \not{\partial} - g \tau \cdot W - g' Y B - g_s T \cdot G) \psi$$

Just like with the snowflake, a mathematical symmetry called 'gauge symmetry' means that the maths coloured in red can be written down starting with the maths in white. Remarkably, these red parts are entirely capable of explaining the interactions between the elementary particles.

In a tad more detail, the Greek symbol  $\psi$  (pronounced 'psi') represents the particles of nature (those in the first three columns of the Standard Model, such as quarks, electrons and neutrinos). The term on the left describes a world in which particles move around without any interactions at all, while those in red encode the branching rules of the particles. For example, the terms involving the W and B symbols specify the rules for emitting or absorbing photons and W and Z bosons, while the term involving the G symbol specifies the rule for emitting or absorbing gluons.

## Glossary

### ELEMENTARY PARTICLE

This is a particle that is not thought to be composed of any smaller particles.

### ELECTROMAGNETIC FORCE

This force is responsible for electricity and magnetism. It governs how fridge magnets work, how atoms stick together, and how light interacts with matter.

### WEAK FORCE

This force is responsible for the nuclear fusion processes that cause the Sun to shine.

### STRONG FORCE

This force is responsible for holding protons and neutrons together inside atomic nuclei.

### SYMMETRY

This is the idea that something looks the same before and after a particular transformation. For example, a square looks the same before and after it is rotated through an angle of 90°.

### GAUGE SYMMETRY

This specific symmetry governs the equations that describe how the elementary particles interact with each other.

### STANDARD MODEL

This brings together all known elementary particles. It is a unified theory describing the electromagnetic, weak and strong forces, but it does not include gravity or dark matter.

### HIGGS BOSON

This particle is responsible for giving mass to the elementary particles.



❶ snowflake even if we're initially shown only one half of it. Symmetry is also the main reason why we find snowflakes beautiful. Remarkably, exactly the same beauty is present in the mathematics governing the rules by which particles move around. Unlike snowflakes, this is not something that can be seen directly, because it isn't the symmetry of a shape. Instead, it is a more abstract symmetry, called 'gauge symmetry' that is encoded into mathematical equations. But it is no less beautiful.

To appreciate this, we can take a look at the equations, though you don't need to be good at maths to appreciate the point we're about to make. Let's suppose that we can write down the equations governing how particles that never interact with one other behave. It is possible to formulate these equations without too much trouble because Einstein's Special Theory of Relativity (which we explored in the first part of this series) more or less dictates what to write. After this first step, we will have the equations to describe a very boring

universe, which is nothing like the one in which we live. For example, it might contain electrons and nothing else, so nothing would stick together and atoms would not exist. The key piece of maths describing such a universe is illustrated on the left-hand side of 'The key idea' and the reason we wrote it down is so that you can appreciate just how simple it is (it easily fits on the back of an envelope).

Now here comes the brilliance of symmetry. If we demand that our



## Quantum theory underpins our modern world”

equations should have a gauge symmetry, then we are absolutely forced to write down the stuff in red on the right-hand side of 'The key idea'. The amazing thing is that the stuff in red is what determines the way particles hop and branch. In other words, starting from a *boring* universe where nothing interacts, symmetry delivers a set of rules that dictate how the particles of *our* Universe interact with each other.

This gauge symmetry tells us, for example, that we must allow for the existence of photons, and it tells us that electrons hop around with the possibility to emit or absorb these photons. That's because without photons it isn't possible to make the maths symmetric. Viewed this way, photons are a consequence of the symmetry. This really is exactly the same as saying that, starting from a picture of half a snowflake, we can use symmetry to draw an entire snowflake. Except that in this case, what we get is much more than what we started out with. As far as anyone can tell, all of the elementary particles interact with each other in ways determined by gauge symmetry.

You might want to know why the equations governing the fundamental rules of nature are so simple, and so snowflake-beautiful in their symmetry. This is a good question, to which we don't yet know the answer. Whatever the reason, it seems that our Universe is built in such a way that the rules governing how particles behave can be encapsulated in remarkably concise mathematics. This is truly awe-inspiring, not least because these rules lie behind all natural phenomena, from the colour of a rose to the burning heart of a star.

### AN UNFINISHED TALE

The most recent vindication of the Standard Model was the discovery of the Higgs boson. This particle was predicted to exist in the early 1960s by several people, including Peter Higgs and François Englert, who together won the 2013 Nobel Prize in Physics (Englert worked in collaboration with the late Robert Brout). The brilliance of their idea lies in the fact that they recognised just how important ❶





François Englert (left) and Peter Higgs, who together won the 2013 Nobel Prize in Physics for their work on the Higgs boson

## Particle physics in five steps



1.

The Universe is built from elementary particles. All of the interactions between these particles can be understood in terms of just four fundamental forces: weak, strong, electromagnetic and gravity.



2.

The enchanting idea of symmetry is crucial in allowing physicists to write down the mathematical equations governing the precise details of these forces.



3.

Thanks to symmetry, the particle physics that underlies all natural phenomena, from the flow of a river to the death of a star, can be encapsulated in a set of astonishingly simple rules.



4.

Without the Higgs boson, the elementary particles would be massless and zip around at the speed of light. They would not form atoms and the world as we know it would not exist.



5.

The Standard Model brings together everything we know about the particles to date. Yet many key unanswered questions remain, such as 'what is dark matter made of?' and 'what is dark energy?'.





• symmetry is in governing the laws of physics. Although gauge symmetry correctly predicts how the particles should interact, it appears, at first sight, to apply only if the elementary particles have zero mass. In other words, adding mass into the equations appears to destroy their symmetry. Since the particles of the real world are most certainly massive, this was a serious problem.

But in a stroke of genius, Higgs, Englert and Brout realised that it is actually possible to preserve the symmetry of the equations at the expense of adding a new particle. This new particle lay undiscovered for nearly 50 years, until it was finally spotted at the Large Hadron Collider in 2012 – the ultimate vindication of the idea of gauge symmetry.

Although the Standard Model of particle physics has been tremendously successful in explaining how the elementary particles behave, we know that it cannot be the whole story. For one thing, it does not include the force of gravity, because nobody has yet



**“We don’t have the equations to describe the laws of physics in places where gravity is strong, such as near a black hole”**

figured out how to write down the equations that consistently bring together Einstein’s theory of gravity with the laws of quantum physics. Fortunately, that stumbling block is not as serious as it sounds because the force of gravity is so feeble that it can be ignored in particle physics experiments. It only becomes important when considering large objects, like planets and stars. Nevertheless, it means that we don’t currently have the equations to describe the fundamental laws of physics in places where gravity is strong, such as in the vicinity of a black hole.

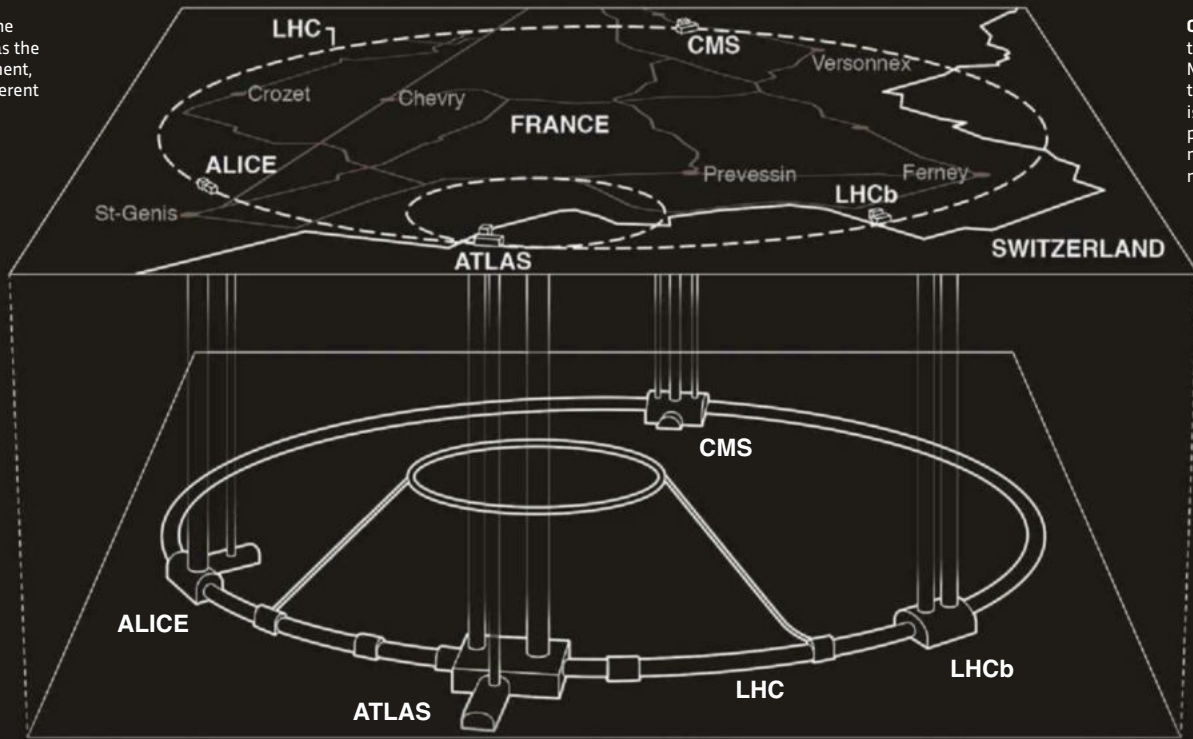
In addition, not one of the particles contained in the Standard Model is a suitable candidate for a ‘dark matter’ particle. This type of matter, which makes up 85 per cent of the entire mass of the Universe, is an enigma. Astronomers have discovered its existence – and mapped its spread across the cosmos – by measuring the gravitational pull it exerts on the ordinary matter around it, but we don’t know what it’s made from.

#### CERN: ABOVE AND BELOW

The Large Hadron Collider (LHC) is the world's most powerful particle accelerator. The LHC resides in a 27km-circumference tunnel at CERN, 100m below the France-Switzerland border. At the LHC, two beams of protons moving within a whisker of the speed of light collide head-on, recreating the conditions that existed close to the time of the Big Bang.

**ATLAS** has the same goals as the CMS experiment, but uses different methods

**ALICE** detects quark-gluon plasma, a state of matter thought to have formed just after the Big Bang



**CMS** is studying the Standard Model, including the Higgs boson. It is also hunting for particles that could make up dark matter

**LHCb** is investigating the tiny differences between matter and antimatter by studying the bottom quark

The fact that there might be new particles in nature in addition to those that we have already seen in various experiments is not too surprising. Nor is it surprising that any such new particle should be 'dark'. Dark simply means that the particle does not emit or absorb photons (in fact, neutrinos are like this too). After all, why should it be that the only particles that exist just happen to be the ones that we can see with telescopes? There is some room for optimism though, because it is conceivable that the Large Hadron Collider will be able to produce dark matter particles in the foreseeable future, which is something to keep an eye out for.

Modern astronomical measurements also reveal the existence of 'dark energy', which is causing distant galaxies to recede from the Earth at an accelerating rate. This too is something that is not explained within the context of the Standard Model. We'll return to this in the next and final article in this series, where we turn our gaze to the heavens and to the Big Bang itself. 🌌

✕

**“After all, why should it be that the only particles that exist just happen to be the ones that we can see with telescopes?”**

**Jeff Forshaw** is professor of particle physics at the University of Manchester. He has co-authored three popular science books with Brian Cox.

**Brian Cox** is professor of particle physics at the University of Manchester and the Royal Society professor for public engagement in science. His BBC TV and radio work includes *Wonders Of The Universe*, *Forces Of Nature*, *Stargazing Live* and *The Infinite Monkey Cage*.



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## HELEN CZERSKI ON... **HOW RAIN AFFECTS TYRE NOISE**

### **"BUT WHY WOULD A CAR ON A WET ROAD SOUND DIFFERENT TO A CAR ON A DRY ROAD?"**

**I**t's the details that astonish me. We humans live inside a complicated deluge of information, with constant light and sound waves whooshing through an environment that is defined by temperature, texture and smell. Yet sometimes your brain manages to pluck something incredibly subtle out of the flood. Recently, I woke up in the morning in an unfamiliar city, and before I had even opened my eyes, I knew that it had rained overnight. When I poked my subconscious a bit to find out why I was so sure, I realised that it was the traffic noise. The sound of cars going past was softer than normal, but I couldn't hear rain. My brain immediately concluded that there was a thin layer of water on the road outside. But why would a car on a wet road sound different to a car on a dry road? Come to that, why do car tyres make any noise at all?

The sound of a car comes partly from the engine and partly from the tyres. Even electric cars produce tyre noise, especially at higher speeds, and it turns out to be tricky to get rid of it completely. There are several sources of sound, but the relevant one here is caused by the tread on the tyres. Every car tyre has a series of grooves, some running all the way around, and some running from the middle to the outside. A completely smooth tyre would be very quiet, and very dangerous. That's because it would only take a little bit of water on the road to fill the gap between the rubber and the road, and if they can't touch, you've got no grip. The grooves give the water somewhere to go. You can see this in action on a wet day – in front of a rolling car wheel, there are several lines of splash where water is being squirted forward from the grooves as the rubber is compressed.



On a dry day, those grooves in the tyres are a source of sound. As trapped air is compressed and shoved outwards, it pushes on the air around the tyre, and that push is transmitted outwards as a sound wave. The grooves running out to the sides are never spaced evenly, and that's because when they are, air is pushed out in regular jets as the wheel rotates, making a single tone that's really annoying. When they aren't evenly spaced, that energy is spread out over a few different frequencies and any people living or working nearby are much happier.

And that's not all. A large part of the sound is produced at the line where the tyre first touches the road. But if you look at that part of a wheel from the side, you'll see that the road and the wheel surface make a horn shape, the gap between them opening up just like an old-fashioned gramophone horn. And beautifully, it has the same effect. The horn shape amplifies the tyre noise, and since wheels are always going to be round, it's pretty

hard to get rid of it.

When the roads are wet, the sound from the air being shoved out of the grooves is replaced by the sound of splashing as water is shoved out instead. But the splashing doesn't disturb the surrounding air nearly as much. It's odd that something as substantial as water actually makes less sound than something as insubstantial as air, but the difference is easy to hear.

It was still pretty early when I first woke up, so I wasn't really in the right frame of mind to appreciate all the subtleties on offer in my soundscape. Confident that I wasn't missing out on a beautiful sunny day, I rolled over and went back to sleep. 🎧

**Dr Helen Czerski** is a physicist and BBC science presenter. Her book, *Storm In A Teacup*, is out now (£8.99, Transworld).

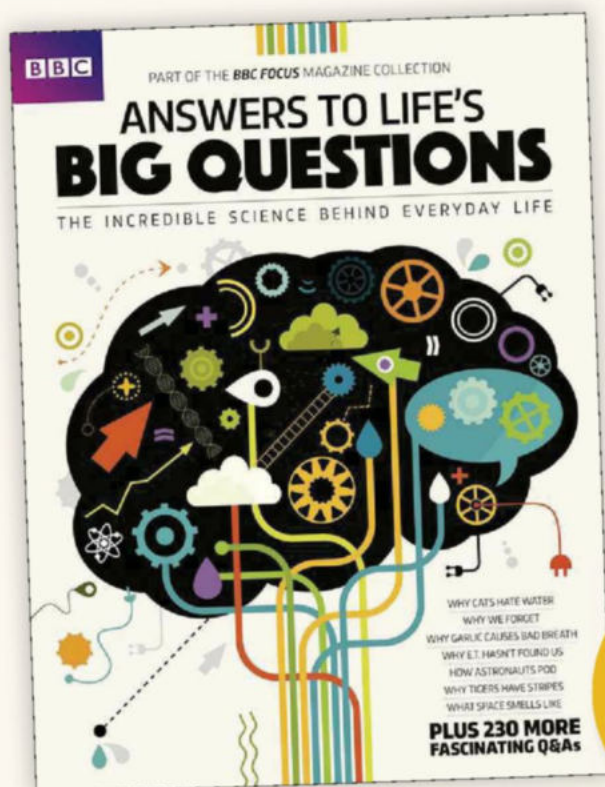
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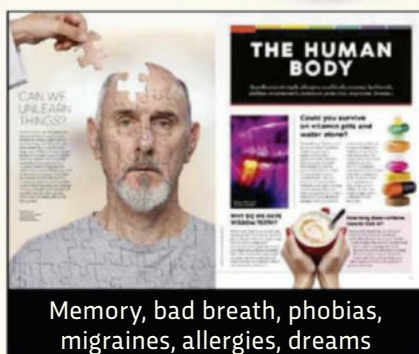
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science writer

# YOUR QUESTIONS ANSWERED

JUNE 2017

EDITED BY EMMA BAYLEY

## Why can't we reach the end of a rainbow?

TOM ROBERTS, LIVERPOOL

A rainbow isn't a fixed object that hangs in the sky. It's an illusion formed between the sunshine, the rain and your eyes. Light bounces out of the raindrops at an angle of  $40^\circ$  for red light, and  $42^\circ$  for blue. And that's true wherever you stand, so as you move, the rainbow moves too and you can never catch it. **LV**





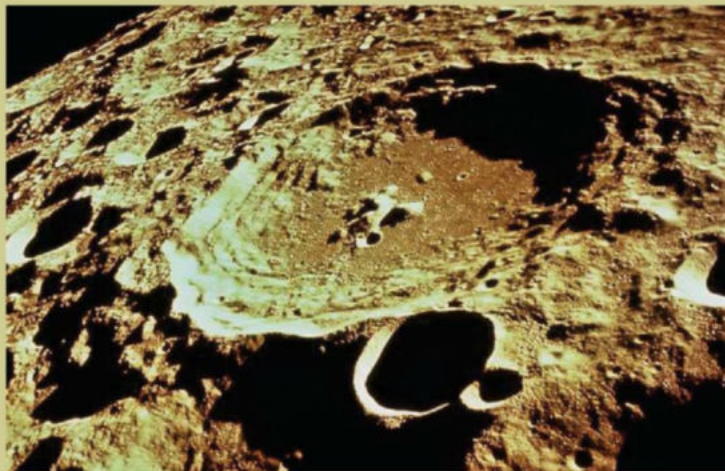
## When we die, do all our cells and organs die at the same time?

ANDY HURMAN, BEDFORD

Definitely not. The brain and nerve cells require a constant supply of oxygen and will die within a few minutes, once you stop breathing. The next to go will be the heart, followed by the liver, then the kidneys and pancreas, which can last for about an hour. Skin, tendons, heart valves and corneas will still be alive after a day. White blood cells, which are more independent, can keep going for almost three days. **LV**

## Why is the far side of the Moon so heavily cratered?

COLIN GRAY, BY EMAIL



It's often thought that the far side is more exposed to incoming impacts, leaving it more battered than the side facing us. In fact, calculations show both sides have been equally affected. The key difference is the far side has a much thicker crust. This thickness has prevented fresh, molten rock emerging from below to cover as many of its craters. **RM**

### IN NUMBERS

# 1,500

The length, in kilometres, of the Great Barrier Reef that has become damaged due to climate change.

# 20

The length, in cms, of the biggest canary species. The São Tomé grosbeak has only recently been identified with DNA analysis.

# 29

The percentage by which blackbirds have increased in the UK since 2007, according to the RSPB.



## Can a fright really turn hair white?

DUNCAN WHERRETT, BERWICK-UPON-TWEED

Hair follicles naturally produce bleaching hydrogen peroxide but this is normally mopped up by the enzyme catalase. As we age, catalase production slows and the hair bleaches itself white or grey. But you have to wait for the hair to grow from the root – once hair emerges from your scalp it is dead. Severe stress could theoretically cause the immune system to cause dark hairs to fall out, leaving just the white ones behind. Nonetheless, there are no scientifically documented cases of this happening after a fright. **LV**



## Why do jokes make us laugh?

YARDEN ALLOUN, SURREY

Laughter plays an important social function, signalling to the joke-teller that we share their perspective on the world and that we recognise their witty intent. Sometimes these guffaws arise spontaneously from genuine mirth, other times it's more strategic: we ingratiate ourselves with the joke-teller by letting them know we appreciate their humour. But actually most of our laughter isn't caused by jokes. We laugh much more often when we're the one doing the talking, but again we're using this 'voluntary laughter' as a social device, conveying feelings of closeness and playfulness to the people we're with. **q**

Lamb's blood has been successfully transfused into a human... but we wouldn't recommend it



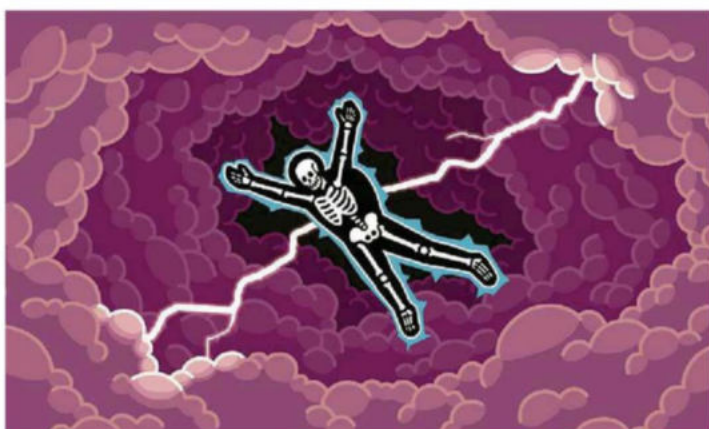
## Do animals have blood types?

BILL ROBINSON, SLOUGH

Yes they do! As long as the animals in question have blood (not all do) then they will have species-specific 'blood groups'. As with humans, these groups are determined by the structure of the blood based on the presence or absence of antibodies along with the make-up of the proteins that sit on the outside of red blood cells. Humans are usually one of four main blood types (although 35 have been identified for us). Thirteen types have been identified for dogs, eight for horses and three for cats. Back in 1667, lamb's blood was successfully transfused into a 15-year-old boy without causing a fatal allergic reaction! **cc**

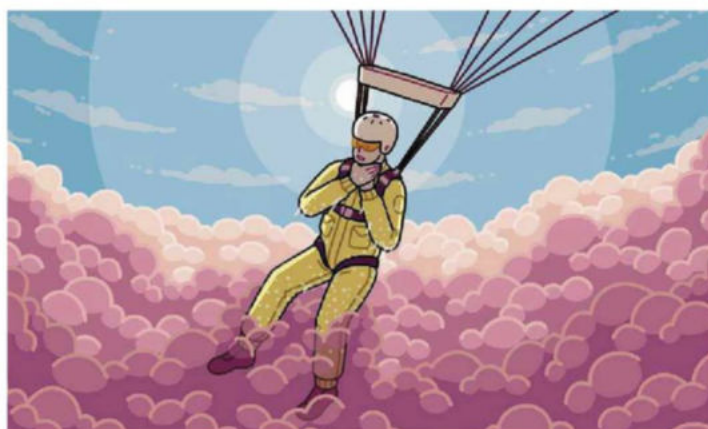
### THE THOUGHT EXPERIMENT

## COULD I SURVIVE A PARACHUTE JUMP THROUGH A THUNDERCLOUD?



### 1. BEFORE PULLING THE RIPCORD

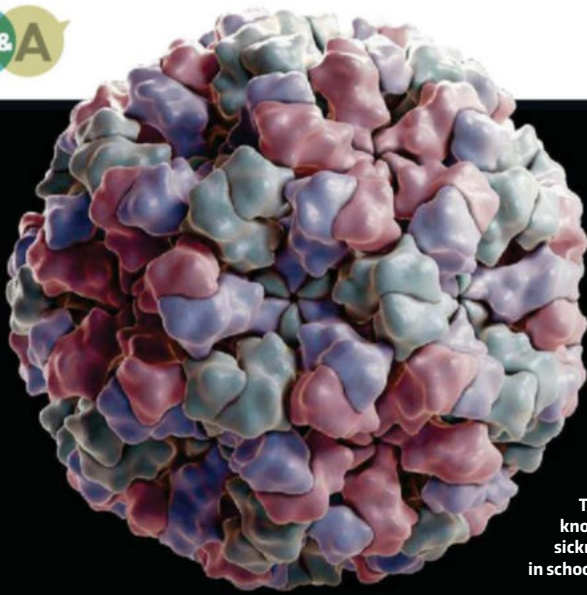
Skydiving through rain can be painful because you're falling at terminal velocity, so the rain is driven into your face at up to 200km/h. In a thundercloud, your chances of being hit by lightning are higher than on the ground because your wet body presents a more conductive path than the air around you. Nearby lightning bolts will jump to you, then continue to the ground. This happens to planes, but the passengers are safe because the metal skin of the plane diverts the bolt around them.



### 2. AFTER PULLING THE RIPCORD

If you try to parachute through the thundercloud, things get much worse. The turbulence can tangle your lines, or wrap you in the canopy, and the updraughts can mean you gain altitude instead of falling. You could be flung so high that you asphyxiate in the thin air, or freeze to death. In 1959 a US Marine pilot called William Rankin ejected from an F-8 Crusader fighter jet directly into a storm. It took him 40 minutes to reach the ground and he suffered frostbite and severe decompression injuries.





The norovirus is known for causing sickness outbreaks in schools, cruise ships and hospitals

## How long can a virus live outside a body?

CHAUDHARY NIKUL, INDIA

Viruses can live for a surprisingly long time outside of a body, depending on conditions such as moisture and temperature. They tend to live longer on water-resistant surfaces, such as stainless steel and plastics. A cold virus can sometimes survive on indoor surfaces for several days, although its ability to cause infection drops dramatically over time. Flu viruses can survive in the air for several hours, especially at lower temperatures, and on hard surfaces they can survive and remain infectious for 24 hours. Enteric viruses, such as norovirus and hepatitis A, can survive for weeks on a surface if conditions are suitable. **ED**

## Could we clone a Neanderthal?

ODYSSEUS RAY LOPEZ, US



The Neanderthal genome was sequenced in 2010. Meanwhile, new gene-editing tools have been developed and technical barriers to 'de-extinction' are being overcome. So, technically, yes, we could attempt the cloning of a Neanderthal. It would involve introducing Neanderthal DNA into a human stem cell, before finding a human surrogate mother to carry the Neanderthal-esque embryo. However, there'd likely be mismatches between mother and embryo that might make the endeavour unfeasible. And, given that the Neanderthal is our closest relative, its cloning would likely be regulated as whole human or reproductive cloning, which in most countries is illegal. **AP**



## Can you turn glass back into sand?

JODIE APPLETON, NEW ZEALAND

Finely crushed glass is basically a very pure form of sand. Technically, natural sand is made of quartz crystals of silicon dioxide, whereas glass is the non-crystalline, amorphous form of silicon dioxide. But when it is ground down enough, the difference isn't obvious. Crushed glass is sold as an alternative to sand for pool filters – in fact, recycled crushed glass has been considered as a partial replacement for the sand on some of Florida's eroding beaches. **LV**

## Which part of the brain generates doubt?

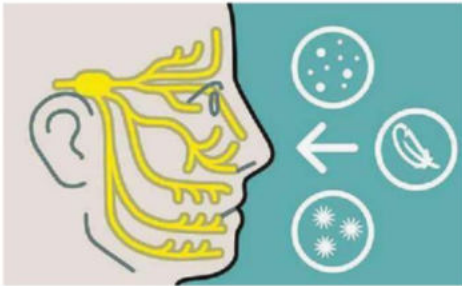
JACK CATALANO, US



Researchers recently discovered that patients with damage to the ventromedial prefrontal cortex (located behind the eyes), had a 'doubt-deficit', in that they were unusually gullible in response to misleading adverts: for example, an advert for a too-good-to-be-true painkiller. But it's important to note that it's very difficult to link complex psychological states – such as the experience of doubt – to specific parts of the brain. Many other neural regions are likely to be involved in the subjective experience of doubt, including more emotional areas, buried deeper in the brain. **CJ**

## ...WHEN I SNEEZE?

In 2012 researchers blew puffs of air over cells cultured from the lining of a human nose to simulate a sneeze. They found the cilia cells beat much faster for several minutes. The beating cilia clear away mucus and trapped germs, so sneezing may help quickly 'reboot' the nose. In people with sinusitis, the cilia don't speed up like this, which might explain why sufferers have prolonged sneezing fits!



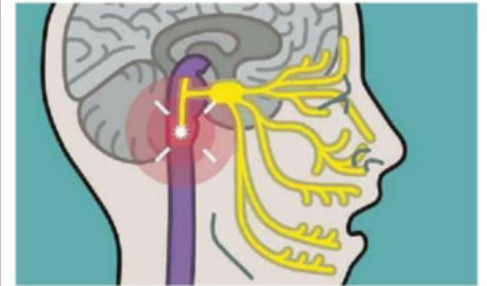
### 1. Nose

A sneeze begins when dust, chemicals or a light touch stimulate the nerve endings of the trigeminal nerve.



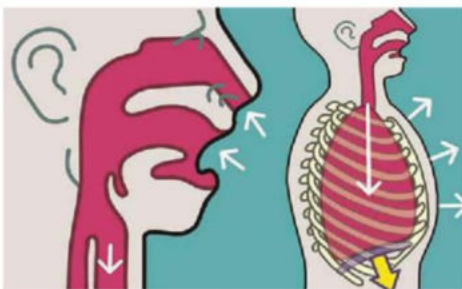
### 2. Eyes

17-35 per cent of people also sneeze when exposed to bright light. This is known as Autosomal dominant, Compelling Helio-Ophthalmic Outburst, or 'ACHOO'.



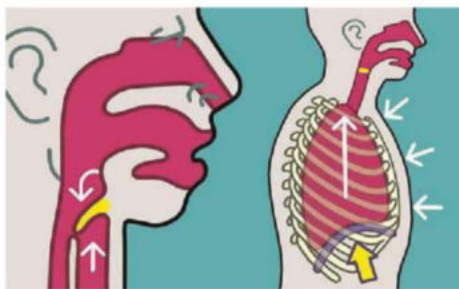
### 3. Brain

The signals travel to the 'sneezing centre' in the lateral medulla of your brain. When they reach a critical threshold, it triggers a sneeze reflex.



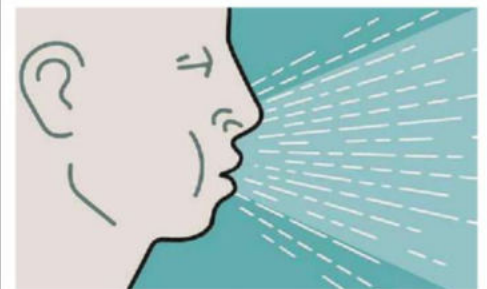
### 4. Diaphragm

The reflex forces a sudden, deep intake of breath. At this point the chain reaction is unstoppable and a sneeze is inevitable.



### 5. Glottis

The glottis at the back of your throat squeezes shut as your diaphragm contracts to build up pressure. Your eyes also squeeze shut.



### 6. Mouth and nose

The pressure is released and air, mucus, dust and germs exit through the mouth and nose at up to 160km/h. This ejection lasts just 150 milliseconds.

## What would happen if the sea level rose by two metres?

RICHARD WREN, LANCASTER

In the last couple of decades, the sea level has risen by about 3.2mm per year – double the average rate last century. A further 2m rise by 2100 is now within the range predicted by many experts. This would put a lot of Cambridgeshire permanently underwater, as well as much of Hull, Great Yarmouth and Glastonbury. But the sea level isn't constant around the globe. Ocean currents and the shape of the land masses mean the waters of the South Pacific and China Sea are already 30cm higher than the average. Falling salinity due to increased rainfall lowers the density of seawater, so the sea level in these areas rises faster too.

Forty per cent of the world's population lives within 100km of the coast, while 250 million people live less than 5m above sea level. Hurricanes and storm surges can magnify even small sea level rises dramatically. Flood levels that would previously be expected just once a century will occur on average once a decade. The US has 20,000km (12,400 miles) of coastline and protecting it will cost \$15bn. Bangladesh fares much worse. It will need 8,000km of dykes over 10m tall to protect it, and without them will lose more than 16 per cent of its total land area, including the Sundarbans mangrove forest – one of the last homes of the Bengal tiger. **LV**



In 2016, more than 3.7 million people were affected by floods in Bangladesh



## Is AI taking away jobs?

TONY BROOKS, LEAMINGTON SPA



AI is not the same as factory automation or robots, so AI is not taking away many jobs. Like the internet, AI is an enabling technology, which is creating whole new industries. The first jobs created are for computer developers, AI experts and researchers, along with sales and marketing people in new AI

companies. Other new jobs include educators, lawyers, and regulators to help society adjust to the changing technologies. For technologies enabled by AI such as self-driving vehicles or smart buildings, we will need construction workers, engineers, and architects to build new infrastructure. That's a lot of new jobs. **PB**

## Why do some buildings hum in high winds?

NATASHA JENKINS, LONDON

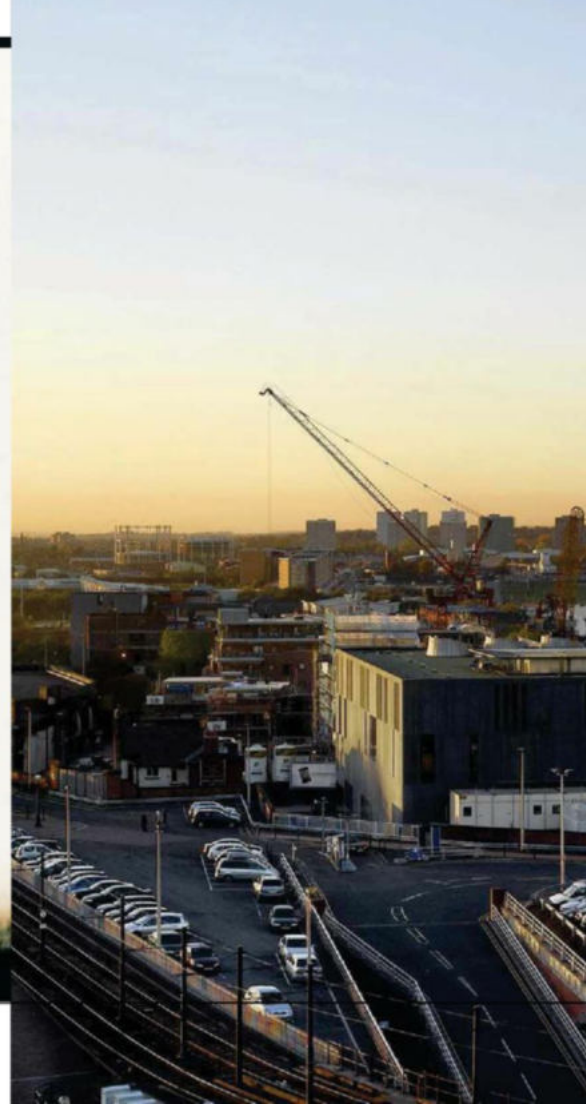
When the wind blows across a building with recesses, louvres or other architectural features, it can start to 'hum', like someone blowing across the top of a bottle or a reed. For example, the 169m-tall Beetham Tower in Manchester makes a note just below middle C. To cure the noise, engineers have to make alterations to the mass and shape of the features that are causing the problem. **RM**

## Is it true that most medicines don't work for most people?

TRUDI BRYON, WAKEFIELD

Many of us find that medicines like painkillers don't seem to work for us. Even when they do, it's tempting to wonder if the ailment just went away by itself.

Over the years, thousands of clinical trials have been carried out to gauge the effectiveness of drugs. But in 2003, a senior executive with pharmaceutical company GlaxoSmithKline made headlines by admitting that more than 90 per cent of drugs only work in 30 to 50 per cent of people. In reality, the situation is even more perplexing, as clinical trials can't reveal if just some people get all the benefit, or if everyone benefits but only some of the time. Some believe better understanding of the genetics of patients will lead to 'personalised medicine', but so far this has only helped with a handful of drugs. **RM**







According to locals, Manchester's Beetham Tower makes a humming noise reminiscent of a UFO

Love our Q&A pages? Follow our Twitter feed @sciencefocusQA



TOP 10

## BIGGEST STARS IN THE MILKY WAY\*

### 1. VY Canis Majoris

Size: 1,800–2,100 x Sun (so massive that its light takes eight hours to travel around its own equator)

Distance from Earth: 3,900 light-years

### 2. RW Cephei

Size: 1,535 x Sun

Distance from Earth: 3,500 light-years

### 3. V354 Cephei

Size: 1,520 x Sun

Distance from Earth: 9,000 light-years

### 4. KY Cygni

Size: 1,420–2,850 x Sun

Distance from Earth: 5,000 light-years

### 5. Mu Cephei

Size: 1,260 x Sun

Distance from Earth: 6,000 light-years

### 6. VV Cephei A

Size: 1,050 x Sun

Distance from Earth: 4,900 light-years

### 7. KW Sagittarii

Size: 1,009 x Sun

Distance from Earth: 7,800 light-years

### 8. Betelgeuse

Size: 887 x Sun

Distance from Earth: 643 light-years

### 9. Antares

Size: 883 x Sun

Distance from Earth: 550 light-years

### 10. V838 Monocerotis

Size: 380 x Sun

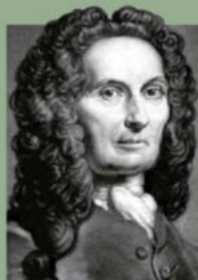
Distance from Earth: 6,100 light-years

\* Not to scale



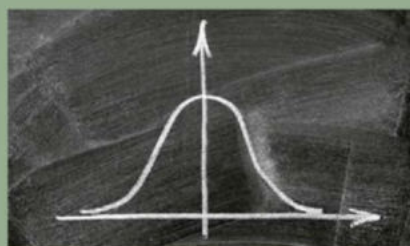
## WHO REALLY DISCOVERED?

## THE BELL CURVE

KARL FRIEDRICH  
GAUSSABRAHAM  
DE MOIVRE

With its central peak and gracefully sloping sides, the Bell Curve is one of the best-known and important graphs in maths and science. Put simply, it shows the spread of values of anything affected by the cumulative effects of randomness. And there's no shortage of those: from stock market jitters to human heights and IQ, many phenomena follow at least a rough approximation of the Bell Curve, with the most common value in the centre, and rarer, more extreme values to either side.

Many textbooks refer to it as the Gaussian Curve, reflecting the fact that the brilliant 19th-Century German mathematician Karl Friedrich Gauss deduced the shape of the curve while studying how data are affected by random errors. But a French maths teacher named Abraham de Moivre arrived at the same curve decades earlier while tackling a problem that had baffled mathematicians for years: how to calculate the frequency that heads or tails appear over the course of many coin-tosses. Most mathematicians refer to the curve simply as the 'Normal distribution', while historians often use the term 'Gaussian Curve' as an example of Stigler's Law of Eponymy, which states that no scientific discovery is named after its actual discoverer. **RM**



## How do corals eat?

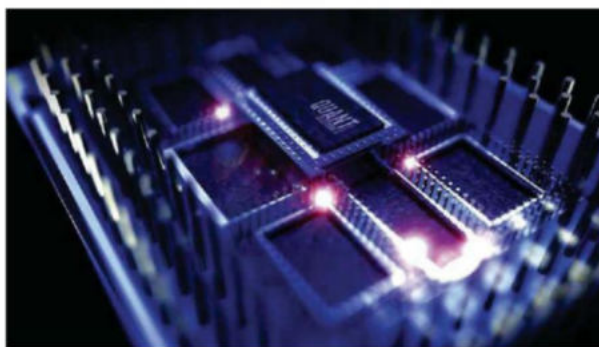
MARY LEONARD, CHELMSFORD

Corals are communal animals related to sea anemones and jellyfish. Like their cousins, they catch tiny animals (called zooplankton) using stinging tentacles that surround the single body opening

that acts as both a mouth and anus. Many corals also contain symbiotic algae called zooxanthellae. The zooxanthellae allow them to get some extra energy through photosynthesis. **LV**

## What kind of logic gates are used by quantum computers?

BRIAN SHIMELL, SURREY



Conventional computers use electrical signals that represent binary 1s and 0s, or bits. Their building blocks are logic gates such as 'AND', 'OR' and 'NOT' which determine whether an output is a 1 or a 0. Quantum computers operate using qubits, which hold all possible states simultaneously, and only when their final state is measured will their final state become a reality. Quantum gates are made by using quantum entanglement, so looking at the state of one tiny particle will tell you about the state of the other. There are many varieties of quantum gate, both in theory and in practice, some resembling conventional logic, some a little bizarre, like 'square root of NOT'. **PB**

## IN NUMBERS

7-9

The estimated percentage of fish that are venomous.

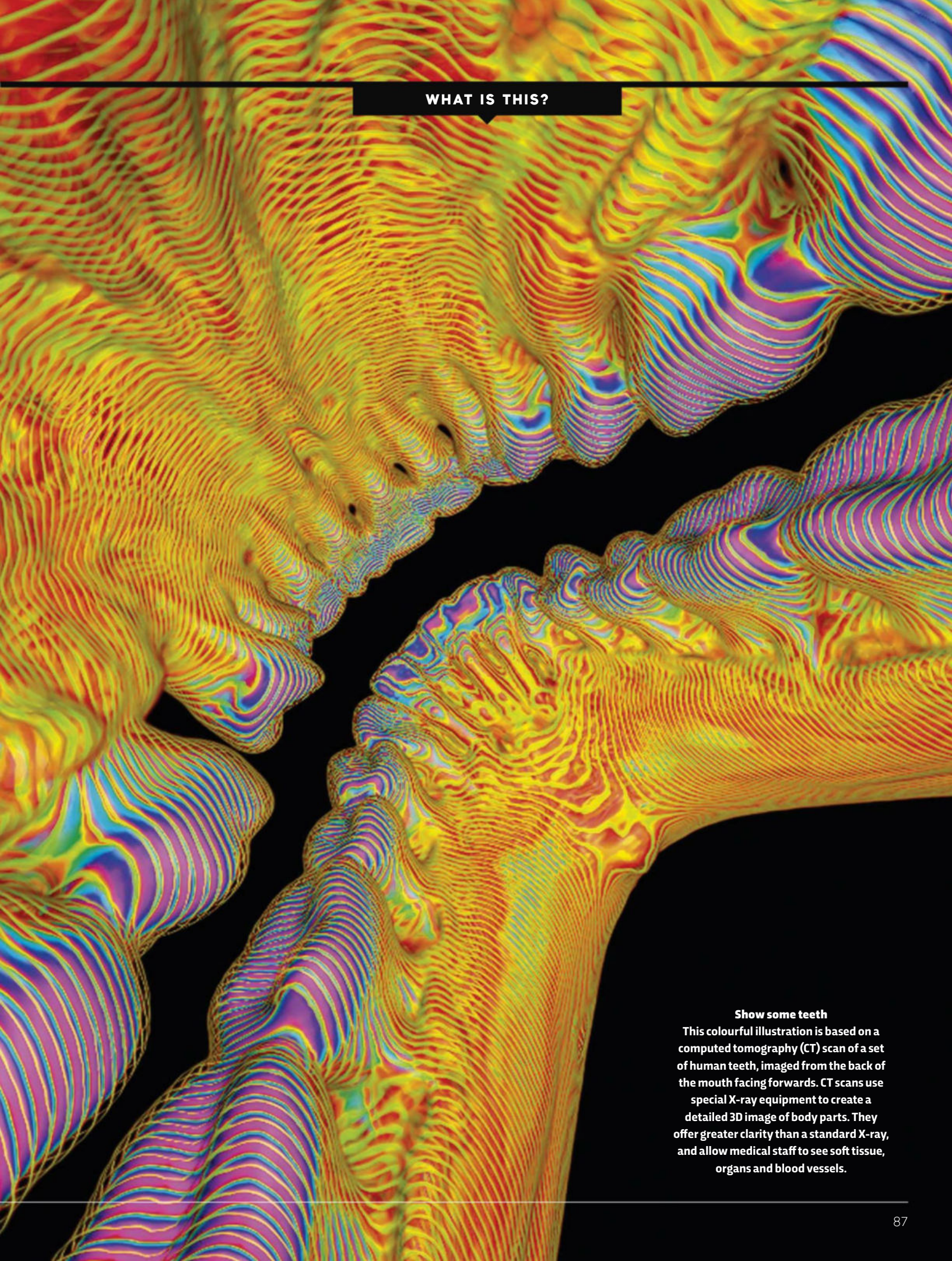
10

The percentage of people affected by delayed sleep phase disorder, making them 'night owls'. It could be caused by a mutation to the gene CRY1.

250

The number of hairs in the average human eyebrow.





WHAT IS THIS?

**Show some teeth**

This colourful illustration is based on a computed tomography (CT) scan of a set of human teeth, imaged from the back of the mouth facing forwards. CT scans use special X-ray equipment to create a detailed 3D image of body parts. They offer greater clarity than a standard X-ray, and allow medical staff to see soft tissue, organs and blood vessels.





Tendons connect muscle to bone; in contrast, ligaments connect bones to other bones

## Is it possible to make tendons stronger?

YASMIN CAINE, CHESHIRE

Tendons are connective tissue structures that attach muscles to bones, allowing us to move our joints. They consist mainly of collagen strands, twisted together to give fibres, which in turn form bundles. Their 3D structure allows them to withstand forces pulling in different directions. Tendons are remarkably strong but prone to injury. Resistance

exercise can strengthen tendons, although they take longer to respond than muscles. Studies on mice with mini-treadmills has shown that exercise increases collagen turnover in tendons, as well as encouraging blood flow. Unfortunately, research suggests that the collagen-boosting effects of exercise are less prominent in women than in men. **ED**

## Why aren't DNA tests 100 per cent accurate?

GARY WARD, US

Assuming there is enough DNA to read, DNA tests should certainly be able to identify genes – how you differ to other groups of people, say, if it were an ancestry test; or whether you have a gene variant associated with a predisposition to disease. But how that is understood, interpreted or used is where things get complicated. Many false-positive and false-negative results can happen because of 'quirks' in our chromosomes. You can get different estimates of how recently we share ancestors. And it's hard to determine the significance of a mutation you may carry. **AP**

DNA tests require a saliva sample, usually taken with a swab



## WHAT CONNECTS...

### ...INSECTS AND COGS?



**1.**

Planthoppers are insects of the Issidae family. They feed by sucking sap from the stems of plants and normally walk very slowly to avoid attracting attention from predators.

**2.**

When threatened, planthoppers can leap over a metre, and can take off with an acceleration of more than 700G.

When not jumping, the hind legs are 'cocked' back against a small spur.



**3.**

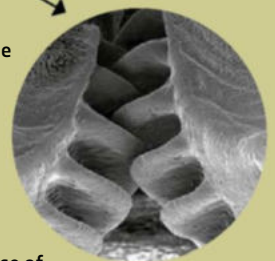
The legs have to be fired backward within 0.03 milliseconds of each other to prevent the insect spiralling out of control.

This level of precision isn't possible using ordinary nerve impulses.



**4.**

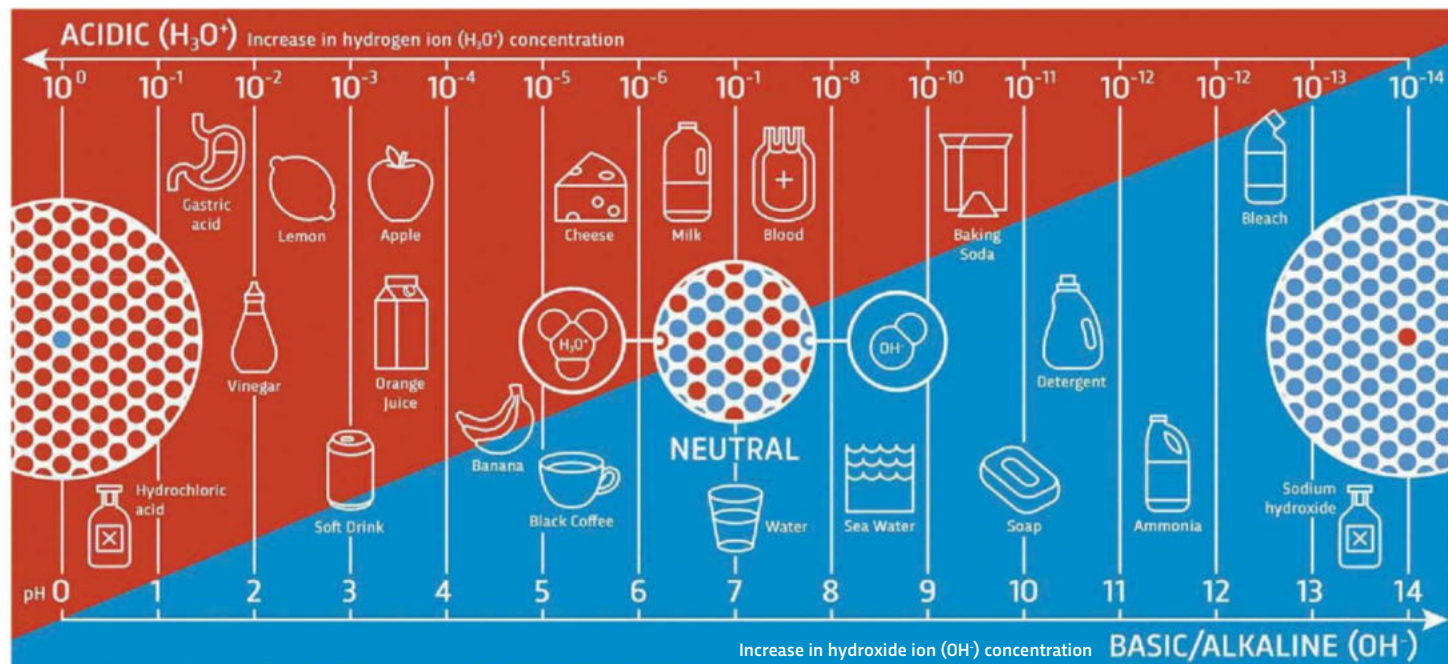
Instead, they are mechanically synchronised by a pair of cogs with teeth just 80 microns wide. This is the first documented case of working gears in nature.



## HOW IT WORKS

# ACIDITY

Acids are molecules that easily become negatively charged. Most acids do this by losing a proton. The stronger an acid is, the more easily it gives up a proton (hydrogen ion). Acidity is measured using the pH scale, which stands for 'potential for hydrogen'. Each step down in the pH scale represents 10 times more hydrogen ions released. So a pH 1 acid is 100,000 times more reactive than a pH 6 acid.




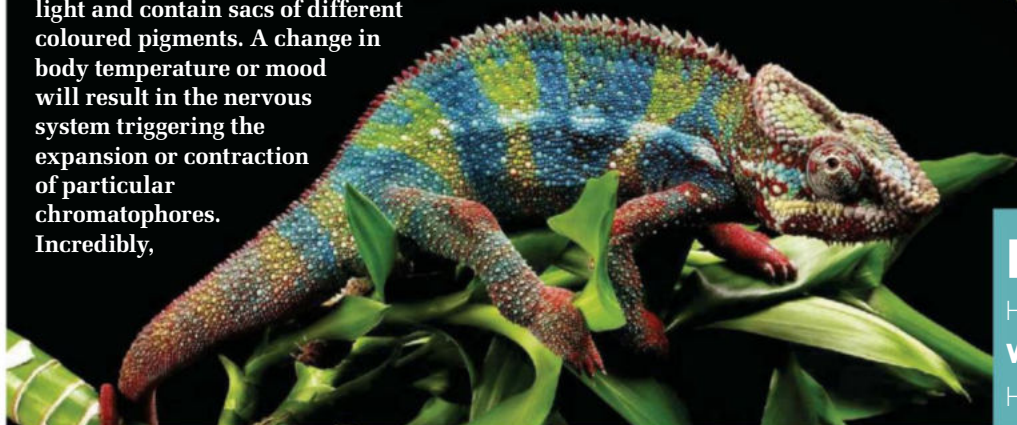
## QUESTION OF THE MONTH

### How do chameleons change colour?

ABIGAIL JONES, YORK

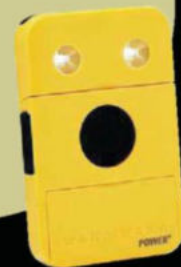
Chameleons may be the masters of disguise but their motivation for changing colour is often more to do with temperature regulation and communication than camouflage. They possess special cells in their skin called chromatophores that reflect light and contain sacs of different coloured pigments. A change in body temperature or mood will result in the nervous system triggering the expansion or contraction of particular chromatophores. Incredibly,

the chameleon can literally 'pick 'n' mix' the colours that are created during this mind-boggling process – all within seconds of responding to an external environmental change or the presence of a potential mate or enemy. 



## WINNER!

Abigail Jones wins a WakaWaka Power+ (£56, [waka-waka.com](http://waka-waka.com)), a durable and compact solar charger that is capable of charging virtually any smartphone within a few hours. It also provides hours of light via its integrated torch, so you can avoid those painful midnight stumbles.



## NEXT ISSUE:

How does glow-in-the-dark work?

What if the Earth had two Moons?

How do microbeads affect fish?

Email your questions to [questions@sciencefocus.com](mailto:questions@sciencefocus.com) or submit online at [sciencefocus.com/qanda](http://sciencefocus.com/qanda)



# OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

JUNE 2017

EDITED BY JAMES LLOYD



PHOTO: DINOSAURS IN THE WILD

01

**DINOSAURS IN THE WILD**

NEC, BIRMINGHAM, 24 JUNE – 24 AUGUST 2017.

EVENTCITY, MANCHESTER, 7 OCT 2017 – 7 JAN 2018.

[dinosaursinthewild.com](http://dinosaursinthewild.com)

## SEE DINOSAURS IN THE WILD

You're driving across prehistoric plains, when a *Triceratops* charges into view, offering an uncomfortably close-up view of its razor-sharp horns. It's the ultimate safari – and now you can experience it at Birmingham NEC.

*Dinosaurs In The Wild* is a live-action experience created by Tim Haines, the man behind the original BBC *Walking With Dinosaurs* series. Through a combination of virtual reality, animatronics and live sets, visitors will be transported back to the Late Cretaceous, 67 million years ago. Once your

time machine has landed, it'll convert into a rugged land vehicle and transport you to TimeBase 67, a research station where scientists are studying living dinosaurs. Here, you'll see *Triceratops* babies squirming inside their shells, and witness a dinosaur autopsy, before visiting the Lookout for panoramic views of the prehistoric life below.

To find out just how the team created this virtual world, we spoke to the park's dino consultant Darren Naish. Turn over to find out how the team brought the dinosaurs to life.





## Q&A: DARREN NAISH

Palaeontologist and *Dinosaurs In The Wild* scientific consultant

### Where does *Dinosaurs In The Wild* take place?

The setting is the Late Cretaceous in western North America, where there's this unique set of animals only found at this time: *Tyrannosaurus rex* and *Triceratops* are the most famous ones, and there are less familiar animals such as a two-legged herbivore called *Thescelosaurus* and a large armoured dinosaur called *Ankylosaurus*. There are also giant aquatic lizards (mosasaurs) and flying pterosaurs, including the bizarre, stork-faced *Quetzalcoatlus*, which had a 10-metre wingspan and stood up to five metres tall.

### What can visitors expect?

You begin your journey by stepping into a 'time machine', which travels back 67 million years. Once you arrive, you're treated to a spectacular CGI sequence as you travel across the prehistoric wilds to your destination: TimeBase 67. This is a research post and visitor centre that you

can walk around, full of life-like specimens and dinosaurs. There's a huge synthetic *Alamosaurus* heart, animatronic dinosaurs being fed, and scientists (played by actors) to guide you around. It's a mixture of state-of-the-art technology and live action.

### How has the latest science informed the experience?

The look and behaviour of the animals is the most up-to-date yet. With the *Quetzalcoatlus*, we now know that they were well adapted to walking on land, probably feeding on small ground animals such as baby dinosaurs – so we've got them doing stuff like that.

There's also recently been a major paradigm shift in our understanding of the life appearance of dinosaurs: we now have widespread evidence of filaments, fuzz and feathers amongst many species, including the theropods, a group of dinosaurs that evolved into modern birds.

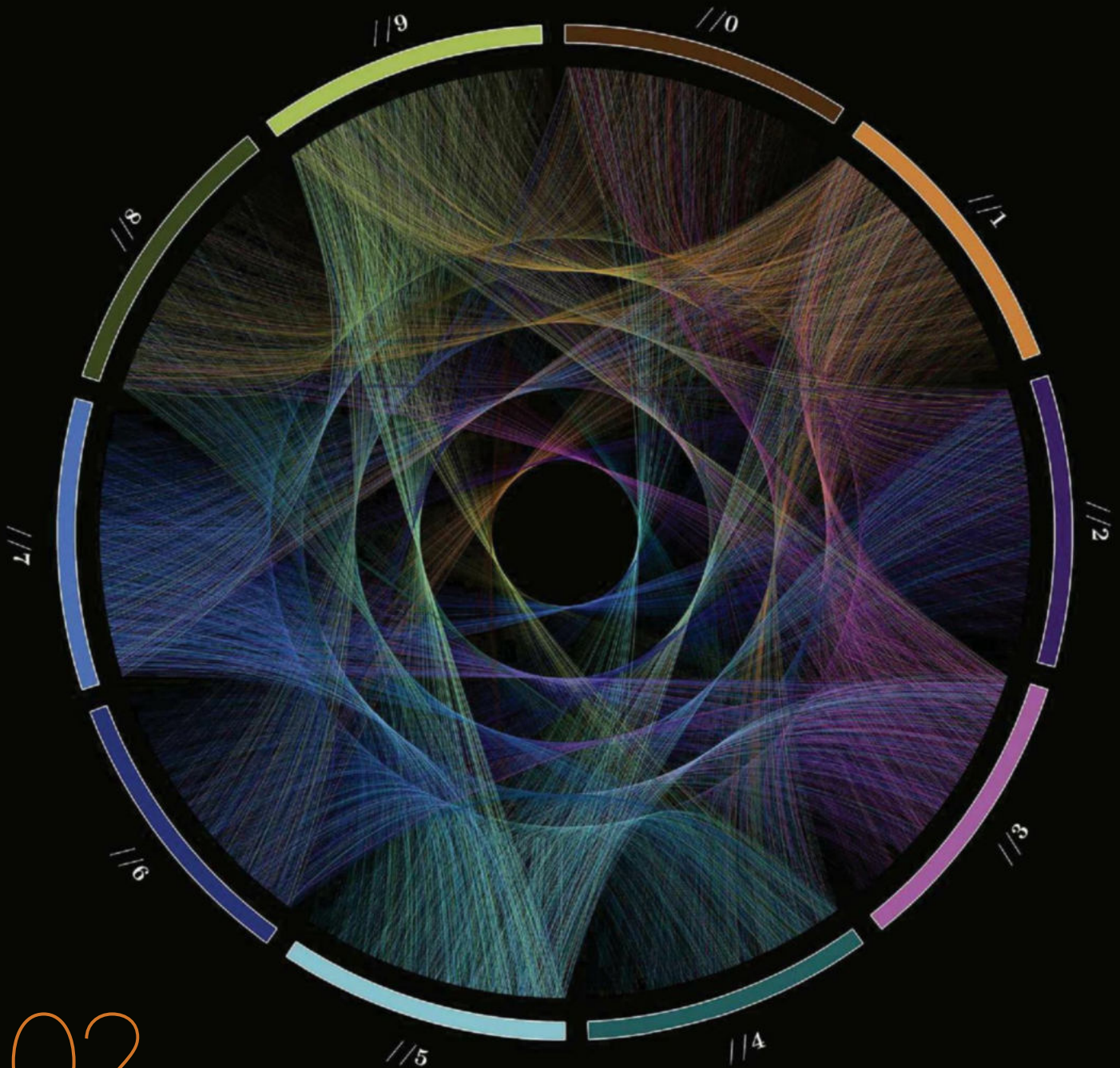
In the case of giant theropods such as *T. rex*, we don't know for sure that the adults had fuzz, but we've gone for it! We've even thought about the sounds of these animals. *T. rex* didn't roar, I'm afraid. It was probably more of a low, internal, rumbling sound.

### What has been your favourite part of the whole experience?

Seeing the computer-generated animals brought to life was incredible. A huge amount of effort has gone into creating screens that feel as if you're looking out of windows: this was one of the first things the team had to get right. So you can stand on the rotunda and look out at three-dimensional moving animals, or peer out of the vehicle's windows as you drive beneath a giant dinosaur. It's going to be amazing fun, with a few scares along the way, and people will hopefully take away a deeper, more dynamic understanding of the Cretaceous world.

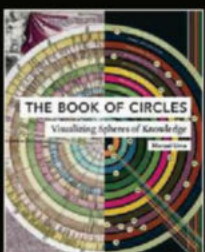


Studying dinosaur limbs is all in a day's work for 'scientists' at *Dinosaurs In The Wild*



02

**THE BOOK OF CIRCLES**  
 BY MANUEL LIMA

 OUT NOW (£26.99, PRINCETON  
 ARCHITECTURAL PRESS).


## GO ROUND IN CIRCLES

It seems that we're hardwired to like circles: studies have shown that we tend to prefer curved objects and shapes to more angular versions, even from as young as five months old. Perhaps it's because we associate sharp, jagged angles with threat and danger, or maybe it's just because we like pizza.

In *The Book Of Circles*, out now, designer Manuel Lima collects together over 300

illustrations that use circles as a way to visualise and understand the world. Highlights include an 18th-Century colour wheel, a visual guide to 65 cheese varieties, a map of data generated by the Large Hadron Collider, and this visualisation of the first 10,000 digits of pi. Created by Cristian Ilies Vasile, it connects each digit of pi to its successive digit, producing an image reminiscent of the pictures we made with our old Spirograph.



## 03

## GEAR UP FOR FESTIVAL SEASON

It may only be May, but we're already (optimistically) stocking up on suncream and camping gear for this year's festivals. Here's our guide to some of this summer's more cerebral offerings.

**CHELTENHAM SCIENCE FESTIVAL**

6-11 JUNE,  
CHELTENHAM.  
[bit.ly/chel\\_scifest](http://bit.ly/chel_scifest)

**OXFORDSHIRE SCIENCE FESTIVAL**

16-21 JUNE,  
OXFORD.  
[bit.ly/ox\\_scifest](http://bit.ly/ox_scifest)

**ALSO FESTIVAL**

30 JUNE – 2 JULY,  
COMPTON VERNEY,  
WARWICKSHIRE.  
[also-festival.com](http://also-festival.com)

**SUMMER SCIENCE EXHIBITION**

4-9 JULY,  
ROYAL SOCIETY,  
LONDON.  
[bit.ly/rs\\_scifest](http://bit.ly/rs_scifest)

**CHELTENHAM SCIENCE FESTIVAL**

Celebrating its 15th birthday this year, the Cheltenham Science Festival is now one of the veterans of the circuit. This year's array of mind-expanding events include appearances from scientist Richard Dawkins, percussionist Evelyn Glennie, TV medic Michael Mosley, and NASA's former chief scientist Ellen Stofan. There are plenty of free, interactive activities in the Discover Zone and MakerShack, and workshops on everything from quantum computing to the science of afternoon tea. Plus, make sure you check out the Science Trail, which was created by yours truly...

**ALSO FESTIVAL**

If you prefer to spend your summers sipping prosecco in a field, then Also Festival offers one of the more upmarket experiences. Set in a landscape sculpted by Capability Brown, events include Prof David Tong on the poetry of gravitational waves and Prof David Nutt on psychoactive substances (not literally). Meanwhile, there's philosophical wine tasting, midnight feasts, alternative cabaret, glow-in-the-dark croquet, perfume making, and wild swimming in the Compton Pools lake. There's even a 'Safari Hotel' of luxury bell tents for those who find the standard camping experience a little too earthy.

**OXFORDSHIRE SCIENCE FESTIVAL**

Oxford is one of the UK's most influential science cities, so it's no surprise that it has a festival to match. Make your own solar mobile phone charger, hear like an insect, crack cyber security and build a star. Plus there's a free, family-friendly Explorazone in Oxford Town Hall on Saturday 17 and Sunday 18 June.

**SUMMER SCIENCE EXHIBITION**

The Royal Society's free summer shindig gives you the chance to meet the experts behind the research. At this year's exhibition, you'll be able to hold a beating robotic heart in your hands, walk through a gallery of glow-in-the-dark sea creatures, and find out how dinosaur scientists are fighting crime on the streets of Britain.

Science festivals  
offer something  
for all the family

At Bluedot, you can dance  
in the shadow of the  
Lovell Telescope



### BLUEDOT

7-9 JULY,  
JODRELL BANK  
OBSERVATORY,  
CHESHIRE.  
[discoverthe  
bluedot.com](http://discoverthebluedot.com)

### LATITUDE

13-16 JULY,  
HENHAM PARK,  
SUFFOLK.  
[latitudefestival.com](http://latitudefestival.com)

### EDINBURGH FESTIVAL FRINGE

4-28 AUGUST,  
EDINBURGH  
[tickets.edfringe.com](http://tickets.edfringe.com)

### GREEN MAN

17-20 AUGUST,  
BRECON BEACONS,  
SOUTH WALES.  
[greenman.net](http://greenman.net)

### BLUEDOT

Taking place at Jodrell Bank Observatory, home of the iconic Lovell Telescope, Bluedot combines two of our biggest loves: music and space. We had a great time at last year's inaugural event, and we've already got our glowsticks ready for this year's headline set from Orbital. Eclectic indie kids Alt-J and alt-rock heroes Pixies fill the other two headline slots, while there's an extensive science programme packed with inspiring talks, family shows, and stargazing. Come and say hello if you see us there. We'll be the ones huddled around a high-tech barbecue.

### EDINBURGH FESTIVAL FRINGE

There are plenty of cerebral goings-on at the world's largest arts festival. Award-winning comedian Samantha Baines returns with a new show celebrating the lost women of science, there's a hip-hop guide to consciousness from Baba Brinkman, and a romp through the past (and robotic?) future of love and desire by consultant psychologist Prof Neil Frude.

### LATITUDE

Latitude can always be relied on for an eclectic bill. There's chart-topping rock (The 1975, Mumford & Sons), comedy galore (Dara Ó Briain, Katherine Ryan, Simon Amstell), and plenty of food for thought at the Wellcome Trust Hub and the Literary & Poetry Arena.

### GREEN MAN

Nestled in the heart of the Brecon Beacons, Green Man is home to a stellar line-up of music, comedy, literature and film, as well as an area dedicated entirely to science: Einstein's Garden. There's also a Workshop Dome, wildlife walks, a VR experience (inside a tent), and an after-hours rave where the music is generated live from computer code.

### WIN

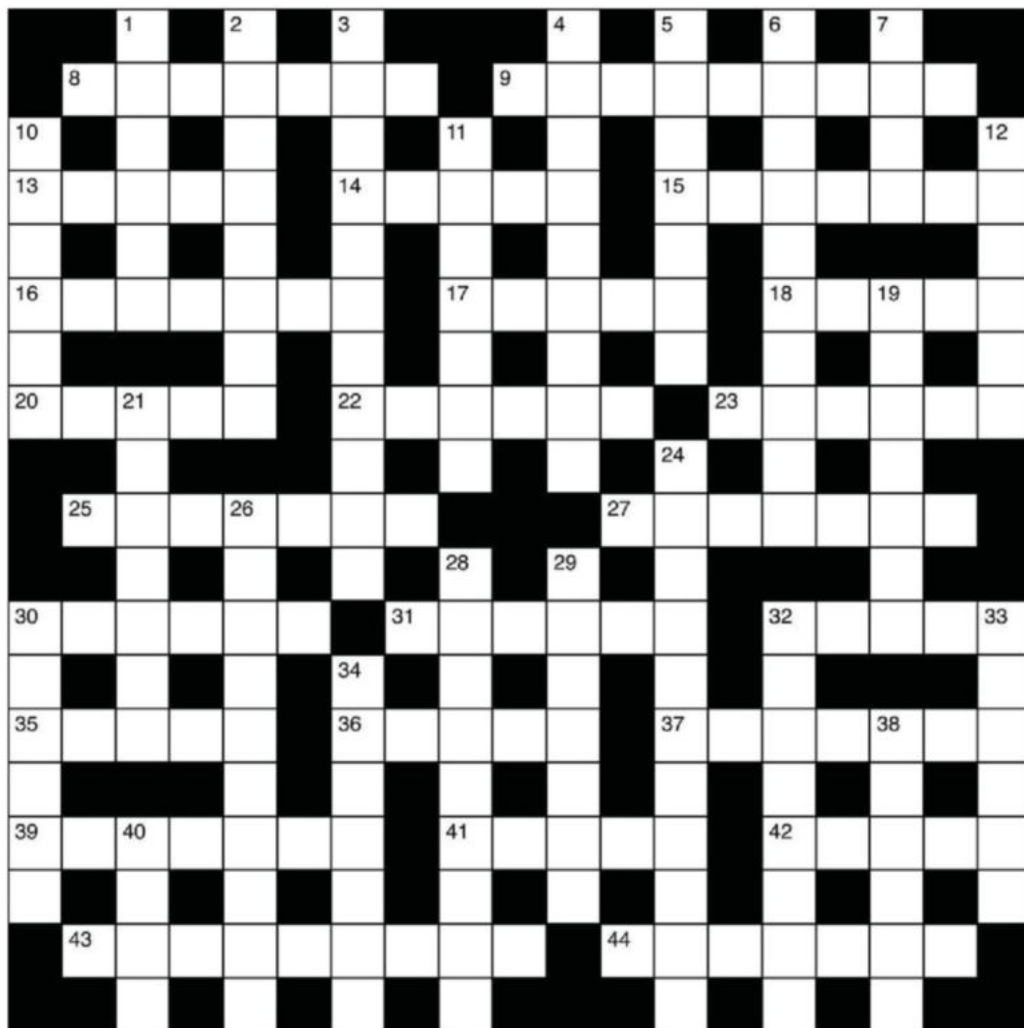
#### BLUEDOT TICKETS

HEAD TO OUR WEBSITE FOR YOUR CHANCE TO WIN  
TWO BLUEDOT WEEKEND CAMPING TICKETS  
[bit.ly/bluedot2017comp](http://bit.ly/bluedot2017comp)



# SCIENCE CROSSWORD

## GIVE YOUR BRAIN A WORKOUT



### DOWN

- 1 Objection to a new English fuel (6)
- 2 Those people have logo design to study (8)
- 3 Element of relativity? (11)
- 4 Prisoner gets more stupid in cooler (9)
- 5 Against detaining that woman with victory badge (7)
- 6 Slam intent displayed by episode (10)
- 7 Relief from herbal medicine (4)
- 10 London area cannot have a function (6)
- 11 Dreadful, crumbling around prop (7)
- 12 Drive to turn green by a year (6)
- 19 Flavouring cooked for fans (7)
- 21 Family has to tear out a protein (7)
- 24 Dual gala can be organised on Pacific Island (11)
- 26 Using different kinds of material about a timid mule (10)
- 28 Copy score displayed by temperature gauge (9)
- 29 Bird has celebrity friend outside (7)
- 30 Old king sees flare set off by daughter (6)
- 32 Fruit on the tongue (8)
- 33 Boy gets answer thanks to composition (6)
- 34 Diary broadcast around – it shows dryness (7)
- 38 Work for politicians (6)
- 40 A shade dull (4)

### ACROSS

- 8 Upset, if such a flower (7)
- 9 Dye used on chalice (9)
- 13 Queen adjusted to a muse (5)
- 14 A shilling and a pound for a mollusc (5)
- 15 Important substance, almost essential, takes time (7)
- 16 Expert sent note when solvent (7)
- 17 Caught goon swimming in river (5)
- 18 Real trouble with small beam (5)
- 20 A grape for a gecko (5)
- 22 Sickness caused by sodium, uranium and water (6)
- 23 By taking pixie right to the top of the tower (6)
- 25 Most expensive insurance payment (7)
- 27 Growth of bacteria shows refinement (7)
- 30 A time to tail new warlord (6)
- 31 Earth provides a reason (6)
- 32 Without a mathematical sign (5)
- 35 Kicks soldier to get mushrooms (5)
- 36 Sort out getting old perch (5)
- 37 The French point to lion, terribly fat (7)
- 39 Encourage chief to be a boffin (7)
- 41 Dog takes one to a papal court (5)
- 42 Range of morning section (5)
- 43 Hotel pie delivered with unknown print (9)
- 44 Laugh, having built construction for fish (7)

### ANSWERS

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# “My dinosaur beers let me share my love of palaeontology with the home brew community”

**Helen Pilcher** chats to **Andrew Farke**, curator at the Raymond M Alf Museum of Paleontology, about his two loves: dinos and home brewing

## So, is there a link between dinosaurs and beer?

There are lots of cool, unexpected connections between brewing and fossils. My favourite is a link between Pilsner beer and the famous half-bird, half-dinosaur fossil, *Archaeopteryx*. Raw barley grains are traditionally turned into malt by briefly germinating them on stone tiles, followed by a ‘baking’ process. The floor tiles of many European malt houses are classically made from Solnhofen limestone, which is a particular type of rock that formed during the Late Jurassic. These are the same rocks in which *Archaeopteryx* and other exquisitely-preserved fossils were found. Making a floor from the stuff is the palaeontological equivalent of using Kobe beef in a McDonald’s Happy Meal!

## Do you name your beer after dinosaurs?

Yes, often. In 2014, some colleagues and I described a dinosaur we had found in Montana. A cousin of *Triceratops*, it’s the oldest horned dinosaur in North America and has a hooked beak, so we called it *Aquilops* – a Greek and Latin combination meaning ‘eagle face’. My colleague celebrated by getting an *Aquilops* tattoo, but I made my first batch of Eagle Face oatmeal stout. I also have a whole series of IPAs named after supercontinents, and I called my first Irish stout The Celtic Elk, after the extinct Irish elk *Megaloceros*.

## Do you name your dinosaurs after beer?

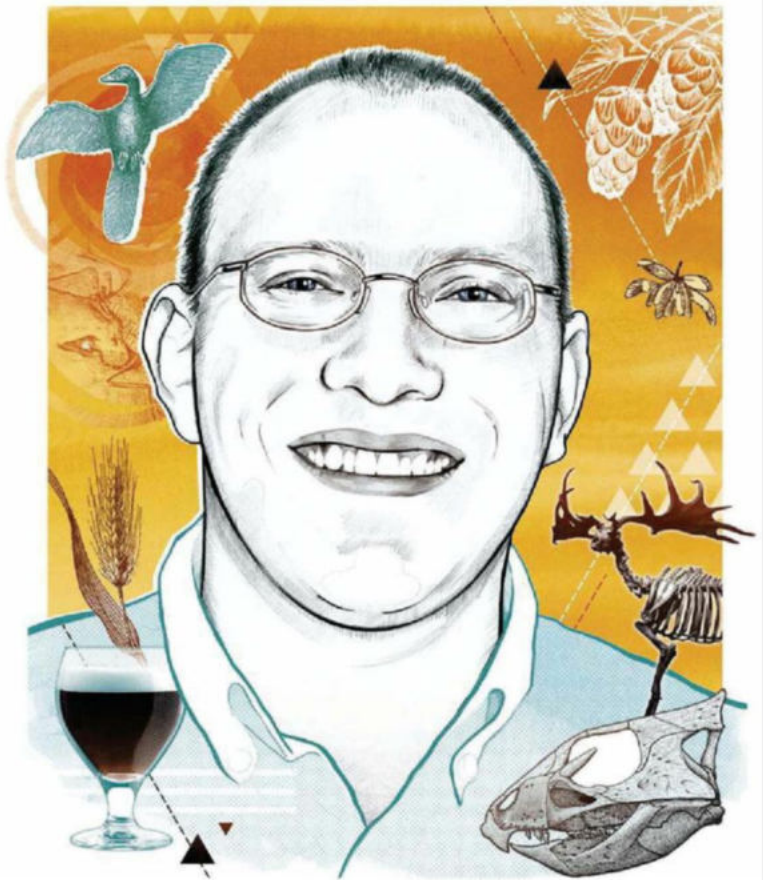
No, I haven’t done that. Maybe I should!

## What’s the geekiest beer you’ve made?

I love brewing new styles and I love a bad beer pun. There’s a German beer called a Munich dunkel, and there’s a fossil fish called *Dunkleosteus*, which lived around 375 million years ago. So I’ve just made a dark lager called Dunkel-Osteus. It’s a match made in prehistoric pun heaven.

## How scientific is brewing?

There’s a creative side to brewing, but there’s also a really fun, scientific side. If you want to make the same beer more than once you have to take careful notes, just like the field notes that I’d take on an excavation. I’m currently playing with water chemistry – looking at what mineral adjustments can be made – and trying different temperatures to ferment the yeast.



## Do the worlds of palaeontology and home brewing overlap?

We palaeontologists often discuss our recent finds over a beer, and a surprising number of palaeontologists brew their own. My dinosaur beers have also given me the chance to share my love of palaeontology with the home brew community.

I also give a lot of talks, where I try to explain how beer is connected with the deep past. There’s a reason why certain regions have great beer-making water, and that has to do with the rocks that formed there many millions of years ago.

## Which is better, dinosaurs or beer?

I don’t know if I can answer that. They’re equally awesome. That’s why I always try and combine them when I can! 🍺

Get your own dino-brewing tips at Andrew’s blog: [andybrews.com](http://andybrews.com)

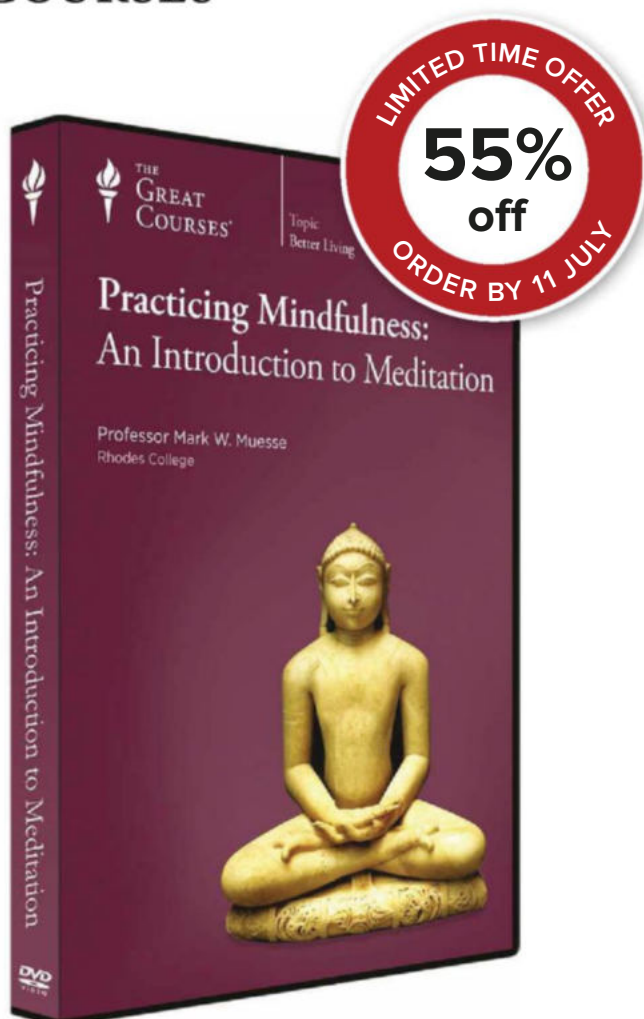
**Dr Andrew Farke** is a curator at the Raymond M Alf Museum of Paleontology in Claremont, California. He is also a volunteer editor for the journal *PLOS ONE*.

### DISCOVER MORE



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